MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Volume 119 No. 4 1959

ANNUAL REPORT OF THE COUNCIL

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NOTICE TO AUTHORS

Presentation of Papers at Meeting

At some meetings of the Society the background and conclusions of selected papers are presented and then discussed. In order to assist the Secretaries in the selection of papers for such meetings, authors are asked to let the Society know, when submitting papers, whether they would be willing to give an account of their paper, if requested.

The attention of authors resident abroad is drawn to the fact that the Society welcomes information about their work. The Secretaries would be happy to consider having such work described at a meeting, in accordance with the author's wishes, either by a Secretary or other Fellow.

Publication of Papers

1. *General.*—It is the aim of the Society to be of the greatest possible service in disseminating astronomical results and ideas to the scientific community with the utmost possible speed. Contributors are accordingly urged to give the most careful consideration to the presentation of their work, for attention to detail will assuredly result in a substantial saving of time.

It is the practice of the Society to seek a referee's opinion on nearly every paper submitted for publication in *Monthly Notices*; experience has shown that frequently the comments of referees have enabled authors to improve the presentation of their work and so increase its scientific value.

2. *Communication.*—Papers must be communicated to the Society by a Fellow. They should be accompanied by a summary at the *beginning* of the paper conveying briefly the content of the paper, and drawing attention to important new information and to the main conclusions. The summary should be intelligible in itself, without reference to the paper, to a reader with some knowledge of the subject; it should not normally exceed 200 words in length. **Authors are requested to submit MSS. in duplicate.** These should be typed using double spacing and leaving a margin of not less than one inch on the left-hand side. Corrections to the MSS. should be made in the text and not in the margin. By Council decision, MSS. of accepted papers are retained by the Society for one year after publication; unless their return is then requested by the author they are destroyed.

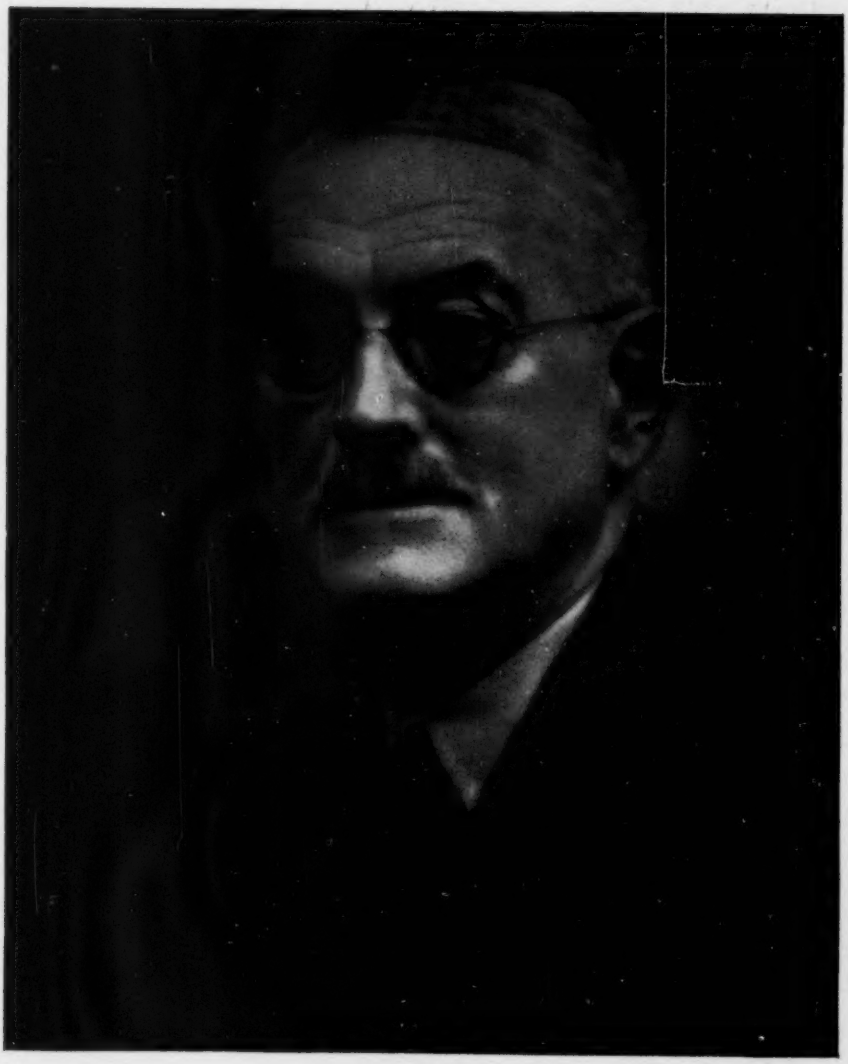
3. *Presentation.*—Authors are allowed considerable latitude, but they are requested to follow the general style and arrangement of *Monthly Notices*. References to literature should be given either in the traditional form of a numbered list at the end of the paper, or as prescribed in *Notes on the Preparation of Papers to be Communicated to the Royal Society*.

4. *Notation.*—For technical astronomical terms, authors should conform closely to the recommendations of Commission 3 of the International Astronomical Union (*Trans. I.A.U.*; Vol. VI, p. 345, 1938). Council has decided to adopt the I.A.U. 3-letter abbreviations for constellations where contraction is desirable (Vol. IV, p. 221, 1932). In general matters, authors should follow the recommendations in *Symbols, Signs and Abbreviations* (London: Royal Society, 1951) except where these conflict with I.A.U. practice.

5. *Diagrams.*—**These should be designed to appear upright on the page, drawn about twice the size required in print and prepared for direct photographic reproduction except for the lettering, which should be inserted in pencil.** Legends should be given in the manuscript indicating where in the text the figure should appear. Blocks are retained by the Society for 10 years; unless the author requires them before the end of this period they are then destroyed. **Rough copies or prints of the diagrams should accompany each manuscript.**

6. *Tables.*—These should be arranged so that they can be printed upright on the page.

7. *Proofs.*—Authors are liable for costs of alteration exceeding 5 per cent of composition. It is therefore in their own and the Society's interests to seek the maximum conciseness and simplification of symbols and equations consistent with clarity.



Dr W. H. Steavenson
President 1957–1959

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY

Vol. 119 No. 4

ANNIVERSARY MEETING OF 1959 FEBRUARY 13

Dr W. H. Steavenson, President, in the Chair

The election by the Council of the following Fellows was duly confirmed:—

Francis Kofi Ampenyin Allotey, Department of Mathematics, Imperial College, London, S.W.7 (proposed by G. J. Whitrow);

Michael Philip Candy, 97 Hawkswood Drive, Hailsham (proposed by G. Merton);

Antony Edward Fanning, London Planetarium, Marylebone Road, London, N.W.1 (proposed by H. C. King);

John Stephen Glasby, 7 Kilwinning Road, Stevenston, Ayrshire (proposed by A. E. Roy);

Francis Leslie Jackson, 11 Glebe Crescent, London, N.W.4 (proposed by H. Wildey);

Shaun Patrick Logue, 7 Mulroy Gardens, Londonderry, N. Ireland (proposed by G. E. B. Stephenson);

John R. Smith, 44 St. John's Road, Sevenoaks, Kent (proposed by J. Heywood); and

Kenneth Ward, 5 Pettits Boulevard, Rise Park, Romford, Essex (proposed by R. G. Foster).

The election by the Council of the following Junior Member was duly confirmed:—

Thomas James McGregor Simpson, 48 Oakbank Crescent, Perth, Scotland (proposed by A. H. Jarrett).

Seventy-eight presents were announced as having been received since the last meeting.

The President gave an address on the award of the Gold Medal to Dr Raymond Arthur Lyttleton (see p. 445).

The President gave an address on the award of the Eddington Medal to Dr James Stanley Hey (see p. 447).

The President gave his address on "The Instruments of Sir William Herschel".

ANNUAL GENERAL MEETING OF 1959 FEBRUARY 13

Dr W. H. Steavenson, President, in the Chair

The Minutes of the preceding Annual General Meeting were read, confirmed and signed.

The Secretary explained that, owing to the greatly increased volume of business now conducted by the Society, a heavy strain was at present placed upon those concerned in producing, auditing and printing the accounts for the calendar year ending December 31 in time for their submission to Fellows at the Annual General Meeting in February. After careful consideration, it appeared to Council that the best solution to this problem was the postponement of the Annual General Meeting until March. It was not proposed, however, to alter the date of the Anniversary Meeting. The Secretary accordingly proposed, on behalf of the Council, the adoption of the following amended form of Bye-law 55, of a new Bye-law 55a, and of certain consequential changes in Bye-laws 8 and 9:—

> *Bye-law* 55.—"A General Meeting of the Society shall be held annually on the second Friday in March, to receive the Report of the Council on the state of the Society and to deliberate thereon; to discuss and determine such questions as may be proposed relative to the affairs of the Society; to elect the officers for the ensuing year; and to enact, alter or repeal Bye-laws, agreeably to the recommendations of the Council, on proper notice given thereto according to the Charter."
>
> *Bye-law* 55*a*.—"The Officers and Council elected at the Annual General Meeting held in February 1959 shall hold office until the next Annual General Meeting to be held in March 1960."
>
> *Bye-laws* 8 *and* 9.—The substitution of "January" for "December" throughout.

The motion was adopted.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year.

The Secretary presented a summary of the Report of the Council for the year 1958.

The Treasurer gave a brief explanation of the Accounts for 1958 and a survey of the Society's financial position.

The Report of the Honorary Auditors was read (see p. 331).

A vote of thanks to the Honorary Auditors of the Treasurer's Accounts for 1958 was proposed and carried unanimously.

It was proposed and carried that the Report of the Council be received and adopted, and that it be printed and circulated in the usual manner, together with the Report of the Honorary Auditors and the President's Addresses.

The Scrutineers reported to the President the result of the ballot, and the names of the Officers and Council elected for the ensuing year were read to the meeting. (The list of names is given on p. 455.)

The retiring President called upon his successor, Professor R. O. Redman, to take the Chair. He did so amid applause, and expressed his thanks to the Fellows for the honour they had done him.

The thanks of the Society were given to the retiring President, Vice-Presidents, and other members of Council.

The thanks of the Meeting were given to the Scrutineers of the ballot.

The Meeting then adjourned.

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The Meeting then adjourned.

REPORT OF THE COUNCIL TO THE

HUNDRED AND THIRTY-NINTH

ANNUAL GENERAL MEETING OF THE SOCIETY

This Report refers to the calendar year 1958

1. *Astronomical publications.*—The production of *Monthly Notices* has continued satisfactorily during the year. The achievement of the past year in reducing the average time-lag between the receipt of a paper and its publication to six months has been consolidated, and the Council is confident of being able to maintain the present position. Russian translations of summaries of original papers have been included for the first time.

The publication of *Occasional Notes* has given some cause for concern. The appointment, first, of a temporary new editor to revive the journal and now of a definitive editor to carry on the work will, it is hoped, lead to more regular publication at an approximate frequency of two to three numbers per year. The Council and the Society are much indebted to Dr Garstang and Dr Dewhirst respectively for undertaking these duties.

During the year the following were published:

Monthly Notices, Vol. **117**, No. 6; Vol. **118**, Nos. 1, 2, 3, 4 and 5.
Occasional Notes, Vol. **3**, No. 20.

2. *Geophysical publications.*—The first number of the new *Geophysical Journal* appeared, as promised, in March, and all four numbers of the first volume were distributed during the year. The success of this new venture has been most heartening. Contributions of very high standard have been submitted and the *Journal* has had an encouraging reception. 736 subscriptions were received in the first year of publication; and the total circulation, including exchanges and part-exchanges, exceeded 1,200. The Council is gratified to know that the Society's new publication is receiving such widespread support, and is most appreciative of the unstinting and energetic service given by the joint editors, Dr H. A. Cook and Dr T. F. Gaskell.

3. *Finance.*—The financial position of the Society this year again shows a welcome improvement as the result of an increase in the number of Fellows and the greater sales of publications, and of other steps taken. The excess of income over expenditure however arose mainly from the Grant-in-Aid for Scientific Publications of £1,000, allocated to us by the Royal Society and received this year in respect of the Society's publications in 1957. But even without it there would have been a surplus of £438 compared to a deficit of £1,338 last year. The amount published this year in astronomical papers was however below the average for the last few years and this would account for more than this surplus. A working margin of income has therefore not really yet been reached.

The results for the *Geophysical Journal* are most encouraging. The number of subscriptions that have come in are sufficient to cover over three-quarters of

the total cost (including distribution) leaving only £682 to be set against part-exchange subscriptions and the Fellowship subscriptions of geophysicists. The Society is indebted to the Nuffield Foundation for a further grant this year of £200 to help the Society to improve the circulation of its publications. This, with the balance of last year's grant has covered most of the cost of advertising the *Geophysical Journal* which included the circularization of some 22,000 leaflets to institutions and members of geophysical organizations.

With the death of Mr Jack Miller, the covenanted gifts made by him, to pay for the Palomar Sky Atlas, ceased. The balance of £359 outstanding has been debited to the Library Fund. If however the other donations he made to the Society are taken into account the cost of these charts and of the cabinet to house them has been more than fully covered through his generosity.

4. *Membership.*—Membership of the Society continued to increase in 1958 though not on the substantial scale of the previous year. The membership table for 1958 is to be found on p. 331.

The Society has lost by death the following Associates:

William Otto Brunner
Knut Emil Lundmark

and the following Fellows:

Harold William Acton
Thomas Noel Burke-Gaffney
*Raymond Fallaw
John Herbert Finch
Henry George Hughes
*John Jackson
Jack Miller
Walter Moss
John Fraser Paterson
*Charles William Dyson Perrins
John Benson Sidgwick
*James Harry Smith

* Life Fellow

Obituary notices for some of these appear on pp. 342–350.

5. *Meetings.*—Eight ordinary meetings were held as usual in Burlington House during the year and also four Geophysical Discussions. In addition, the Society met in Keele, Staffordshire, on July 9–11 at the invitation of the authorities of the University College of North Staffordshire.

Astronomers from overseas who attended the Society's meetings include: Professor A. Danjon (Paris), Dr M. W. Feast (Pretoria), Professor T. Gold (Harvard), Dr A. B. Severny (U.S.S.R.), Dr A. D. Thackeray (Pretoria) and Dr M. S. Zverev (U.S.S.R.).

6. *Awards.*—The Gold Medal for 1958 was awarded to Professor André Danjon for his contributions to astronomical photometry, to fundamental astronomy and to the design of astronomical instruments.

The Eddington Medal for 1958 was awarded to Dr Horace W. Babcock for his work on the magnetic fields of early-type stars and of the Sun.

The following three Associates were elected in 1958:

Francis Birch
Boris Vassilevitch Kukarkin
Yngve Ohman.

7. *Staff.*—The Society is most fortunate in having no changes to record in its permanent staff, from whom it continues to receive splendid and devoted service and who are carrying out the business of the Society with such efficiency and dispatch. Occasional help has been received from Mrs M. B. Knight who has taken some of the increased load of routine accounting, etc., from our Assistant Secretary, enabling him to devote more of his time and great energy to his editorial and general work. Miss Wadsworth has unfortunately after all not felt able to undertake the sorting of dead correspondence, but this can await a more suitable occasion.

8. *The Society's representatives.*—Representatives of the Society were appointed during the year as follows:

on the Board of Management of the Isaac Newton Observatory,
Dr M. W. Ovenden; and
on the Board of Visitors of the Royal Greenwich Observatory
Dr R. L. Waterfield.

REPORT OF THE HONORARY AUDITORS FOR THE YEAR 1958

We have checked the official list of Fellows against the subscriptions received and have examined the relevant part of the professionally audited accounts of the Society. There has been a steady increase of membership in the year 1958, and we note with satisfaction that in a large number of cases outstanding subscriptions have been paid. The suggestion in last year's report of sending invoices to Fellows living abroad was implemented and seems to have produced good results.

We have examined the premises of the Society and are satisfied with the general standard of cleanliness and orderliness. We note, however, that the paint work on the walls and ceiling of the staircase is beginning to deteriorate: we feel that redecoration would greatly improve the appearance. Also, the lighting in the library rooms, although adequate for occasional use, is not sufficient for comfort: we recommend that the possibility of installing fluorescent lighting be considered.

We wish to thank the Assistant Secretary for the ready assistance given to us throughout the audit.

T. KIANG.
K. H. FEA.

PROGRESS AND PRESENT STATE OF THE SOCIETY

	Patron	Institutional Members	Fellows		Junior Members	Associates	Total
			Compounded	Annual Contributors			
1958 January 1	1	7	185	1003	35	53	1284
Since elected	...	...	...	73	13	3	89
Junior Members elected to Fellowship ..	...	...	...	11	−11	...	...
Deceased 1958	...	...	−4	− 6	...	−2	−12
Deceased before 1958, notified 1958 ..	...	...	...	− 1	...	...	− 1
Since compounded	...	...	1	− 1	...	...	...
Resigned 1958	...	...	...	−18	...	...	−18
Removed 1958	...	...	...	−26	− 1	...	−27
Adjustments	...	...	−2	...	...	...	− 2
1959 January 1	1	7	180	1035	36	54	1313

(N.B.—Sixteen Associates are also Fellows, and are therefore counted twice in the above table.)

Balance Sheet

1957 £		£	£
	General Fund		
	Balance at 1958 January 1	24,284	
	Add Donations	16	
		24,300	
	Less Net Loss on Sale of Investments	138	
		24,162	
	Add Excess of Income over Expenditure for 1958	1,438	
24,284			25,600
	Trust and Special Funds		
	Capital at 1958 January 1	7,695	
	Income Balances 1958 December 31	2,144	
9,886			9,839
2,532	*Library Fund*—As per Account		2,129
	Repairs and Maintenance Reserve		
	Balance at 1958 January 1	307	
	Add Transfer from Income and Expenditure Account	350	
		657	
	Less Expenditure 1958	45	
307			612
	Composition Fees Reserve Fund		
	Balance at 1958 January 1	2,323	
	Received in 1958	83	
		2,406	
	Less 6 per cent transferred to Income and Expenditure Account	144	
2,323			2,262
	Staff Pensions Fund		
	Balance at 1958 January 1	513	
	Add Transfer, General Fund Income and Expenditure Account...	100	
		613	
	Less Pensions payable during year	92	
513			521
	Nuffield Foundation Grant		
	Balance at 1958 January 1	109	
	Add further grant	200	
		309	
	Less Transfer to Publications Income and Expenditure Account ...	309	
109			- -
	Amounts received in Advance		
208	Contributions	138	
369	Publications 1959	335	
			473
	Sundry Creditors, including provision for printing publications for		
3,741	1958 not yet completed		3,495
£44,272			£44,931

1958 *December* 31

1957 £		£	£	£
	Investments as per Schedule			
	General Fund valued as at 1922 December 29, or at subsequent cost (Market Value £34,361)		32,244	
32,126				
8,778	Trust and Special Funds valued at cost (Market Value £8,450)		9,673	
				41,917
	Debtors			
	General		1,200	
	Income Tax Recoverable—			
	General Fund		565	
	Trust and Special Funds		94	
	Palomar Sky Atlas Fund		42	
	Payments under Covenant...		43	
1,828				1,944
	Deposits at Savings Banks			
14	General Fund		14	
641	Trust and Special Funds		66	
				80
	Balance on Current Accounts at Bank and Cash in Hand			
205	General Fund		984	
407	Trust and Special Funds		6	
				990
	Fund Overdrawn			
	Mr. Jack Miller's Gift Palomar Sky Atlas Fund			
	Balance at 1958 January 1...		272	
	Payments on Palomar Sky Atlas during 1958		187	
			459	
	Less Received in 1958 under Deed of Covenant... ...	58		
	Income Tax not yet refunded	42		
	Transfer Balance to Library Fund	359		
273			459	
£44,272				£44,931

Note.—Contributions unpaid at 1958 *December* 31 *amounting to* £323 *have not been included in the Accounts.*

£500 was received during the year under the Will of Wilfred Hall, Esq., and was paid over to the County Borough of Preston towards the cost of removal and re-erection of the telescope at Alston, Lancs. (See *M.N.* **118**, 303, 1958.)

General Fund Income and Expenditure

1957		*Expenditure*	£	£	£
£		To Salaries and Wages including Pensions Premiums, and			
2,675		National Insurance		2,738	
	„	*General Expenses:*			
324		Miscellaneous Printing	206		
255		Postages and Packing	298		
273		Lighting and Heating	318		
214		House Expenses	217		
76		Meeting Expenses	73		
106		Insurance, and Telephones	109		
97		Stationery and Office Expenses...	139		
57		Travelling Expenses	39		
4		*Subscription to National Central Library and A.S.L.I.B.*	– –		
84		Accountants' Fees	63		
15		Gold Medal	15		
4		Repairs—Office Furniture etc	3		
6		I.A.U. Telegram Service	6		
65		Sundries	63		
				1,549	
4,254					4,287
215	„	Block Subscription to *The Observatory*			215
262	„	Reproduction of photographic slides, prints and films ...			157
—	„	Keele Meeting Expenses			19
	„	*Publications Account:*			
3,781		Transfer, Excess of Expenditure over Income for the year			1,407
	„	*Transfers:*			
100		Staff Pension Fund		100	
100		Library Fund		100	
150		Repairs and Maintenance Reserve		350	
					550
—	„	Excess of Income over Expenditure for the year transferred to General Fund			1,438
£8,862					£8,073

To the Fellows of the Royal Astronomical Society

We have examined the above Balance Sheet and Accounts with the books and vouchers the information and explanations given to us. We have verified the Investments, and Balances Fellows, which have been inspected by the Society's Honorary Auditors.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET, LONDON, E.C.2.
1959 *January* 22.

Account for the year ended 1958 December 31

1957		*Income*	£	£	£
	By	*Amounts received from Fellows:*			
		Admission Fees—			
		Current Year	103		
		Arrears	90		
				193	
		Annual Contributions—			
		Current Year	4,111		
		Arrears	244		
				4,355	
3,979				4,548	
	„	*Composition Fees:*			
148		Transfer from Reserve Account		144	
50	„	Special Donations from Compounders		25	
100	„	Mr. Jack Miller's Benefaction		100	
					4,817
1,449	„	Interest and Dividends (less Foreign Taxation)		1,508	
18	„	Interest on Bank Deposit Accounts		15	
					1,523
	„	*Miscellaneous Receipts:*			
		Sale of Palomar Slides and Prints		132	
		Sale of R.A.S. Slides and Prints		153	
		Loan of Films		30	
		British Astronomical Association		168	
		London Mathematical Society		40	
		Sundries		10	
580					533
	„	*Editorial Services:*			
1,200		Charged to Publications Account			1,200
	„	Excess of Expenditure over Income for 1957 transferred			
1,338		to General Fund			- -
£8,862					£8,073

relating thereto and certify them to be correctly drawn up therefrom, and in accordance with at Banks. We have not examined the records relating to contributions and admission fees of

W. B. KEEN & CO.,
Chartered Accountants.

General Fund Income and Expenditure

Publications

1957 £		*Expenditure*	£	£
	To	Printing etc.		
		Monthly Notices:		
		Vol. 117 No. 6	544	
		Vol. 117 (binding)	19	
		Vol. 118 Nos. 1–5	2,298	
		Geophysical Journal:		
		Vol. 1	2,182	
	„	Russian translators' fees	98	
	„	Reprints	750	
	„	Paper Supply	850	
	„	Postages and Packing	689	
8,808				7,430
	„	Reserve for Printing:		
		Monthly Notices Vol. 118		
		No. 6 (estimated)	600	
		Occasional Notes Vol. 3		
		No. 20 (estimated)	160	
650				760
191	„	Advertising Leaflets etc. (see contra—Nuffield Grant)		555
1,200	„	Transfer, General Fund Income and Expenditure Account, for editorial services		1,200
£10,849				£9,945

Library

1957 £			£	£
	To	*Costs:*		
163		Purchase of Books and Periodicals	243	
123		Binding of Books and Periodicals	48	
31		General Expenses	45	
				336
	„	Transfer: *Mr. Jack Miller's Gift—Palomar Sky Atlas Fund:*		
—		Balance of Fund overdrawn at 1958 December 31		359
2,532	„	Balance carried to Balance Sheet		2,129
£2,849				£2,824

Account for the year ended 1958 December 31

Account

1957		*Income*	£	£	£
	By	Sales:			
		Monthly Notices Vol. 118	2,236		
		„ „ „ 117	53		
		„ „ „ 116 and earlier	573		
2,094				2,862	
—		*Geophysical Journal* Vol. 1		2,134	
644		*Geophysical Supplements*		145	
490		*Memoirs, Occasional Notes* and miscellaneous publications		163	
1,283		Reprints		1,017	
291		Part Exchange subscriptions		258	
					6,579
	„	Nuffield Foundation Grant:			
191		Balance of Grant allocated for Advertising etc. ...			309
4,993					6,888
	„	Reserve for Printing included in Accounts at 1957			
2,075		December 31 : *Monthly Notices* Vol. 117, No. 6 ...			650
	„	Parliamentary Grant in Aid of Scientific Publications,			
—		through the Royal Society (grant for 1957)			1,000
	„	Transfer, General Fund Income and Expenditure Account, being excess of Expenditure over Income			
3,781		for the year			1,407
£10,849					£9,945

Fund

1957			£	£
£				
2,562	By	Balance brought forward at 1958 January 1		2,532
—	„	Proceeds of Sale of Discarded Books		122
	„	*Trust Income transferred:*		
34		Turner and Horrocks Fund	16	
153		Harry Watson Fund	54	
				70
	„	*General Fund:*		
100		Allocation from Revenue		100
£2,849				£2,824

Nominal £	*Fixed Interest Stocks*	*Book Value* £	£
1,000	Anglo-American Corpn. of South Africa 5¾ per cent Convertible Unsecured Notes	1,009	
1,000	Bowater Paper Corpn. Ltd. 5¾ per cent Convertible Unsecured Loan Stock 1978/82	1,022	
1,000	British Electricity 4¼ per cent Guaranteed stock, 1974/79	1,053	
500	British Petroleum Co. Ltd. 6 per cent Convertible Debenture Stock, 1976/80	517	
1,000	Exchequer 3 per cent Stock, 1962/63	945	
1,000	Imperial Chemical Industries Ltd. 5¼ per cent Convertible Unsecured Loan Stock, 1977/79	1,136	
500	Richardsons, Westgarth & Co. Ltd. 6 per cent Convertible Unsecured Loan Stock, 1976/81	499	
4,500	Treasury 3 per cent Stock, 1966 or after	3,347	
	(Market Value £8,999)		9,528
	Sterling Industrial Equities		
600	Apex (Trinidad) Oilfields Ltd. Ord. 5s. Stock units	1,217	
300	Associated Electrical Industries Ltd. Ord. £1 Stock	754	
1,800	British Motor Corpn. Ltd. Ord. 5s. Shares	888	
625	British Tabulating Machine Co. Ltd. Ord. £1 Shares	1,068	
500	Courtaulds Ltd. Ordinary £1 Stock	925	
500	Elliott Automation Ltd. Ord. 5s. Shares	448	
300	English Electric Co. Ltd. Ord. £1 Stock	886	
160	Fisons Ltd. Ord. £1 Stock	545	
40	Hudson's Bay Co. Ord. £1 Shares	392	
2,000	Investment Trust Units	1,138	
1,000	London & Thames Haven Oil Wharves Ltd. Ord. 5s. Shares	553	
150	Metal Box Co. Ltd. Ord. £1 Stock	521	
600	P. & O. Steam Navigation Co. Ltd. Deferred Ord. £1 Stock	971	
600	Porrits & Spencer Ltd. Ord. £1 Stock	1,010	
800	Richardsons, Westgarth & Co. Ltd. Ord. 10s. Shares	835	
170	Shell Transport & Trading Co. Ltd. Ord. £1 Regd. Stock	1,433	
600	South African Distilleries & Wines Ltd. Ord. £1 Stock	914	
600	Taylor, Woodrow Ltd. Ord. 5s. Shares	664	
750	United Molasses Co. Ltd. Ord. 10s. Stock Units	1,329	
	(Market Value £18,367)		16,491
	Canadian Industrial Equities		
60	Canadian Bank of Commerce Capital Stock $10 Shares	1,090	
50	Dominion Stores Ltd. NPV Shares	848	
50	Imperial Oil Ltd. NPV Shares	1,072	
50	Power Corpn. of Canada Ltd. Common NPV Shares	1,187	
	(Market Value £4,754)		4,197
	U.S.A Industrial Equities		
100	International Utilities Corpn. Common $5 Shares	1,044	
80	Tri-Continental Corpn. Common $1 Shares	984	
	(Market Value £2,241)		2,028
	(Total Market Value £34,361)		£32,244

Trust and Special Funds

Details of these funds will be found in the Quinquennial Report published last year*. No additions were made to the capital funds during the year. The following summarises the position on 1958 December 31.

Investments

The capital and invested incomes of the funds are represented by:—

Nominal £	s.	d.		*Cost* £
457	4	5	British Electricity 4½ per cent Guaranteed Stock 1974/79	405
100	0	0	4 per cent Defence Bonds	100
2,000	0	0	Exchequer 3 per cent Stock 1962/63	1,889
375	0	0	Savings 3 per cent Bonds 1955/65	376
1,765	17	8	„ „ „ „ „ 1960/70	1,766
5,247	6	5	Treasury 3 per cent Stock 1966 or after	3,304
1,902	6	3	3½ per cent War Stock	1,833
			(Market Value £8,450)	£9,673

Income Balances

Special Funds:	£
Victor Nadarov Fund (1950)	355
Arthur Stanley Eddington Commemoration Fund (1948)	102
Benevolent Fund (1950)	28
Trust Funds:	
Lee and Janson Fund (1834 and 1879)	114
Turner and Horrocks Memorial Fund (1853 and 1876)	– –
Hannah Jackson (née Gwilt) Fund (1861)	45
Harry Watson Memorial Fund (1923)	– –
George Darwin Lectureship Fund (1926)	119
A. G. Stillhamer Trust (1937)	430
E. W. Brown Trust (1939)	654
Plummer Bequest (1946)	297
	£2,144

These accumulated income balances are represented by:—

	£
£2,000 Exchequer 3 per cent Stock 1962/63 (at cost)	1,889
£88 12s. 0d. Defence 4 per cent Bonds (at cost)	89
London Trustee Savings Bank Deposits	66
On Current Account at Bank	6
	2,050
Income tax recoverable	94
Total accumulated income (see Balance Sheet)	£2,144

The two gilt-edged holdings are also included in the investment list above.

* *M.N.*, 118, 301–307.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE PRESENTED GIFTS (OTHER THAN BY EXCHANGE) TO THE LIBRARY DURING THE YEAR 1958

Academy of Sciences, Czechoslovakia
Academy of Sciences, U.S.S.R.
The Admiralty
Akademie der Wissenschaften zu Berlin
Astronomical Society of South Africa
Astronomical Society of Tasmania
Astronomische Gesellschaft
British Astronomical Association, N.S.W. Branch
British Records Association
John Calder (Publishers) Ltd.
Capodimonte Observatory
Cartuja Observatory
Centre National de la Recherche Scientifique
Commonwealth Scientific and Industrial Research Organisation, Australia
Defence Research Board, Canada
Faber and Faber, Ltd.
Griffith Observatory
H.M. Nautical Almanac Office
Harvard College Observatory
High Altitude Observatory, Boulder, Colorado
Imperial Chemical Industries
Institut d'Astrophysique de l'Université de Liège
International Astronomical Union
International Council of Scientific Unions
International Scientific Radio Union
Leander McCormick Observatory
Maria Mitchell Association
Editions Albin Michel
National Research Council of Canada
Pergamon Press, Ltd.
George Philip and Son, Ltd.
The Editors of *Rise Hvezd*
Royal Alfred Observatory, Mauritius
Science Council of Japan
The Editors of *Scientific American*
Sky Publishing Corporation
Sociedad Astronomica de Mexico
Specola Astronómica Vaticana
University of Gothenburg
University of London Library
Universytet Marii Curii Sklodowskiej i Lublin
Universitätssternwarte, Munster
University of Pennsylvania Press
United Nations Educational, Scientific and Cultural Organisation
The Editors of *Urania*
Carl Zeiss Verlag

Dr G. Alter
Mr J. C. Begg
Dr C. E. R. Bruce
Mr C. M. Cade
Mr F. Crook
Mr J. W. Dungey
Mr D. Eckhartt
Mr K. S. Jewson
Mr C. E. Kenney
Professor G. C. McVittie
Dr H. Menzel
Mr H. W. Newton
Mr A. Due Rojo
Mr O. Rosenbach
Dr G. De Vaucouleurs
Col. J. A. Watson
Mr D. Wattenberg
Mr J. Xanthakis

OBITUARY NOTICES

WILLIAM OTTO BRUNNER was born on 1878 July 7 in Wattwil, Switzerland. After having been in trade for five years, he studied mathematics and physics at the Swiss Federal Institute of Technology from 1900 to 1904. During the next four years Brunner was teaching mathematics in Chur and then from 1908 to 1926 at the Girls' College in Zürich. In 1910 he passed his examinations for the Doctorate at the University of Zürich with a study on " Beiträge zur Kenntnis gewisser Eigenbewegungen in Sonnenfleckengruppen ". Brunner is the author of several popular books, such as *Die Welt der Sterne* (1947) and *Pioniere der Weltallforschung* (1951). In 1926 he was appointed Director of the Swiss Federal Observatory in succession to Professor A. Wolfer, and Professor of Astronomy at the Swiss Federal Institute of Technology and at the University of Zürich. In this capacity he continued the sunspot-statistics started by Rudolf Wolf, the results of which he published in Nos. 116–145 of the *Astronomische Mitteilungen der Eidgenössischen Sternwarte* and in Volumes VII and VIII of the *Publikationen*. In 1928 the International Astronomical Union entrusted the Swiss Federal Observatory with the publication of the *Quarterly Bulletin for Character Figures* (from 1939 *Quarterly Bulletin on Solar Activity*), of which Brunner edited Nos. 1–68. In 1931 Brunner became a member of the Joint Commission on Solar and Terrestrial Relationships and in 1932 president of the Commission for Character Figures of Solar Phenomena. From 1939 to 1945 he was a member of the Executive Committee of the International Astronomical Union.

William Brunner retired in 1945, in which year he was elected an Associate of the Society. He died on 1958 December 1.

M. WALDMEIER.

KNUT EMIL LUNDMARK was born in Älvsbyn in the northern part of Sweden on 1889 June 14. His death on 1958 April 23 marks the passing of yet another of the pioneers in the field of galactic and extra-galactic research. Apart from visits to the United States in 1920–22, 1929 and 1952 Lundmark's scientific life was centred in Sweden. He was educated at Uppsala where he took his doctor's degree in 1920 and where he remained as docent until 1929. In that year he succeeded Charlier as Professor of Astronomy at the University of Lund and as Director of the Observatory. The directorship necessarily led to some diminution of his personal research, but if the output of the Observatory in the next quarter of a century is any criterion he must have been an inspiring leader of the work of his colleagues.

To appreciate Lundmark's contribution to astronomy it is necessary to recall the state of galactic and extra-galactic research in the years immediately following the first world war. By then Shapley had established the now generally accepted structure of our own galactic system, and as early as 1917 H. D. Curtis had realized the importance of novae as indicators of the distances of the extra galactic nebulae. There was no agreement, however, on the relation of the extra-galactic nebulae to our own galactic system, and the year 1920 saw the National

Academy of Sciences stage a full-dress, though inconclusive, debate on the problem. This was just the problem on which Lundmark had been working, and as early as 1919 he had given a brief summary of his results (*A.N.*, **209**, 369, 1919). Clearly everything turned on more accurate estimates of the distances of the extra-galactic nebulae, and after carefully reviewing various methods Lundmark concluded that the novae provided the most accurate distance-indicators and from them placed M31 at a distance of some $1{\cdot}7 \times 10^5$ parsecs—in order-of-magnitude agreement with Hubble's estimate of $2{\cdot}75 \times 10^5$ obtained nine years later. If the distances of the extra-galactic nebulae were of this order they should of course show no internal proper motions, and on re-measuring van Maanen's plates of M33 Lundmark was indeed able to show (*M.N.*, **85**, 865, 1925) that the supposed rotational motion was some 12 times smaller than had hitherto been supposed and only one quarter of its standard error—a result confirmed at Mt Wilson some ten years later.

From Slipher's radial velocities Lundmark showed in his 1919 paper that, with respect to the globular clusters and the extra-galactic nebulae, the Sun was moving in the plane of the Milky Way. Returning to this question in 1924 (*M.N.*, **84**, 747, 1924) he pointed out that not only was the motion in this plane but also it was directed at right angles to the direction to the galactic centre which "might suggest that our local cluster is revolving around this centre". The motion with respect to the extra-galactic nebulae showed a positive K-term of some 800 km sec^{-1}, and a year later he suggested (*M.N.*, **85**, 865, 1925) that the K-term depended upon the distance. Thus, though the rotation of the galactic system and the recession of the extra-galactic nebulae are correctly associated with the names of others, there can be little question of their anticipation by Lundmark in his pioneer investigations. Lundmark must therefore hold an honoured place amongst the leaders of research on galactic and extra-galactic structure, and by electing him to Associateship the Society showed some recognition of this fact.

H. H. PLASKETT.

HAROLD WILLIAM ACTON, who died on 1958 December 14 after a short illness, was born on 1889 November 24. He had been a Fellow of the Society for 43 years.

Entering the Royal Greenwich Observatory in 1905, straight from one of the local schools from which, when Sir William Christie was Astronomer Royal (and later), the junior computing staff was normally recruited, he soon attracted notice by his facility in the routine reduction of meridian observations.

This facility was further exemplified when his duties were extended to making the observations themselves, and before long he had become remarkably dexterous as an observer also.

His term of service as a computer having expired in 1910, he was employed for a time in the clerical department of the London County Council; but in 1912 he was appointed to a position on the permanent staff of the Observatory where he subsequently took charge of the reduction of Transit Circle observations. After the installation of the Cooke reversible transit circle in 1936 he was intensively occupied in the protracted and meticulous investigation of the characteristics of this fine instrument.

He retired in 1950, with the rank of Senior Experimental Officer.

During his long service (which, between 1916 and 1918, was again temporarily interrupted—this time by war work in the chart department of the Admiralty) his professional activities were almost entirely confined to the meridian branch; and in particular he possessed the unique distinction of having measured and reduced every one of the 2000 and more plates taken between 1912 and 1939 with the Cookson Floating Zenith Telescope for the determination of latitude variation.

In person he was of a rather diffident and self-effacing temperament, and never married. His passing breaks one of the not many remaining links with the Greenwich Observatory of Edwardian days.

W. M. WITCHELL.

THOMAS NOEL BURKE-GAFFNEY was born in Dublin on 1893 December 26, entered the Jesuit order in 1913, and studied in Jersey and at the National University of Ireland. He was ordained as a priest in 1926 and came to Australia in 1928 (after an earlier short visit in 1921) to be senior science master at St. Ignatius' College, Riverview, Sydney.

In 1946 he was appointed Assistant Director of the Riverview College Observatory and became Director in 1952 when Father D. J. K. O'Connell left Riverview to become Director of the Vatican Astronomical Observatory. Father Burke-Gaffney occupied the post with distinction until his death on 1958 September 19 and more than maintained the reputation which Riverview has held as one of the world's first-class seismological observatories.

His published works include the seven papers on seismology listed below. Australia is singularly free from earthquakes for a land mass of its size, and Burke-Gaffney's first paper on the seismicity of Australia was a painstaking survey of those earthquakes since 1883 for which not-too-imprecise estimates could be made of epicentres. His second paper gives details of a comprehensive search for the phase *PKJKP* on Riverview records, and showed the difficulties of the practical problem of establishing the solidity of the Earth's inner core from observations of this phase. The third paper was a study of *T* waves recorded at Riverview from twenty-five earthquakes in the region of New Zealand over the period 1932 to 1954.

The remaining four papers were all concerned with seismological aspects of four hydrogen-bomb explosions of 1954. With the aid of a time clue in news concerning Japanese fisherman, Burke-Gaffney was able to associate an impulse on a Riverview record with the first of these explosions. He then assembled in painstaking detail, and found significance in, data from routine reports from overseas observatories where, in many cases, there had been unawareness that the ground movement recorded was not from a natural earthquake. Subsequently he and I estimated origin-times for the explosions which proved to be correct to 0·0, 0·4, 0·7 and 0·1 second, respectively. The seismological value of the work lay first in the corrections indicated to travel-time tables at distances less than 90°, and secondly in certain abnormal readings between distances of 137° and 142°, which yielded evidence on the structure of the inner core. The importance of the evidence lay in the high precision of the inferred travel-times compared with that of corresponding data from natural earthquakes.

At the time of his death, Father Burke-Gaffney was working on seismic data from certain 1956 nuclear explosions.

His success as a seismologist came primarily from his remarkable insight into the reading of seismic records. He was the type of seismologist, now becoming rare, to whom the records of each earthquake take on the form of a distinct personality, and we may not see his like in Australia again. He was always most willing to help young men from my theoretical University department to an understanding of the intricacies of seismic recording, and my collaboration with him over the past decade has been one of my happiest scientific associations in Australia. He also helped young seismologists from many other parts of the country, and few outside his Sydney colleagues know how far he taxed his strength in his services to others.

He played a valued part in Australia's International Geophysical Year work as Convener of the National Sub-committee on Seismology, and was for several years a member of the Council of the Royal Society of New South Wales.

He was most unassuming and self-effacing. He lived austerely, and only his close College friends and seismological colleagues got to know him well. But those of us who did, knew him as a charming and liberal-minded man, graced with a gentle dignity and a delightful humour. He was also noted at his College " as a naturalist with an uncanny ability to tame wild creatures, and an unorthodox teacher of physics who used improvised and ingenious devices for illustrating complicated principles ".

Publications.—(1) " Seismicity of Australia ", T. N. Burke-Gaffney, *J. and Proc. Roy. Soc. N.S.W.*, LXXXV, 47–52, 1952; (2) " A search for the phase *PKJKP* ", T. N. Burke-Gaffney, *Bull. Seism. Soc. Amer.*, **43**, 331–334, 1953; (3) " The *T*-phase from the New Zealand region ", T. N. Burke-Gaffney, *J. and Proc. Roy. Soc. N.S.W.*, LXXXVIII, 50–54, 1954; (4) " Seismological and related aspects of the 1954 hydrogen bomb explosions ", T. N. Burke-Gaffney and K. E. Bullen, *Austral. J. Physics*, **10**, 130–136, 1957; (5) " Evidence relating to the Earth's inner core from hydrogen bomb explosions in 1954 ", K. E. Bullen and T. N. Burke-Gaffney, *Nature*, **180**, 49–50, 1957; (6) " Diffracted seismic waves near the *PKP* caustic ", K. E. Bullen and T. N. Burke-Gaffney, *Geophys. J.*, **1**, 9–17, 1958; and (7) " On the seismological aspects of the 1954 hydrogen bomb explosions ", T. N. Burke-Gaffney and K. E. Bullen, *Austral. J. Physics*, **11**, 318–321, 1958.

K. E. BULLEN.

JOHN JACKSON was born on 1887 February 11, in Paisley. At the age of 16 he entered Glasgow University. At that time his principal interest was chemistry but he was quickly attracted to mathematics and when he graduated M.A. in 1907 he was top of his year in mathematics. The following year he took the B.Sc. degree with special distinction in mathematics, natural philosophy, astronomy and chemistry. Many of the students taking honours in mathematics attended the astronomy classes conducted by Professor Ludwig Becker. Under Becker, Jackson received a thorough grounding in spherical and dynamical astronomy, learnt the adjustment and use of the principal astronomical instruments, and computed the ephemeris of a minor planet from the elements of its orbit. The teaching of Professor Becker turned his thoughts toward an astronomical career. He had been appointed Ewing Fellow in 1907 but as there seemed no hope of obtaining an appointment from Glasgow, he decided to go to Cambridge if possible. He was awarded a major scholarship at Trinity College in

1909. In his second year he was given the Sheepshanks Exhibition. He obtained a first class in the Mathematical Tripos, Part I, in 1910 and in Part II (with distinction in advanced subjects) in 1912, being then awarded the Tyson Gold Medal in Astronomy. He was awarded a Smith's Prize in 1914.

Jackson had been appointed a McKinnon Research Student of the Royal Society in 1913, taking as the subject of his research the motion of the eighth satellite of Jupiter, which had been discovered by Melotte at Greenwich in 1908. His first published papers were concerned with retrograde satellite orbits and with the discordances between the observed and predicted positions of JVIII. In 1914 he was appointed Chief Assistant at the Royal Observatory, Greenwich and resigned the McKinnon Studentship. At that time the staff of the Observatory was depleted, most of the younger members being absent on war service. Jackson undertook a large amount of routine observing, particularly with the Airy Transit Circle. Throughout his astronomical career he continued to take pleasure in observing.

At about this time Jackson collaborated with F. J. M. Stratton in editing Vol. V of the Scientific Papers of Sir George Darwin, published by the Cambridge University Press in 1916.

In 1917 he was granted a commission in the Royal Engineers, with a view to taking part in sound ranging, for which he attended courses at Chatham and Southampton. The critical position of the allied armies in the spring of 1918 resulted in his being posted to the Fourth Army in France as a Trigonometrical Survey Officer, for which his knowledge and experience were well suited.

In February 1919 Jackson returned from France to Greenwich and at once settled down to systematic work. Sir Frank Dyson entrusted to him the preparation for publication of the observations of double stars that had been made at Greenwich with the 28-inch refractor in the years 1893–1919. This led to a life-long interest in double stars. He determined the orbits of a number of binary systems and in collaboration with H. H. Turner derived the hypothetical parallaxes of 556 double stars from the observed orbital motion, assuming the mass of the system to be known. These parallaxes were used to compute the cross linear velocities from the proper motions and to derive the speed and direction of the solar motion. For 15 years, beginning in 1919, Jackson contributed the double-star notes to the Society's Council Reports.

When Jackson went to Greenwich the standard clock was a Dent regulator. Wireless time signals had made possible the intercomparison of time as determined at Greenwich, Paris and Washington and had shown the need for a standard clock with a more uniform rate. In November 1924 Sir Frank Dyson obtained a Shortt Free Pendulum Clock, and it at once became apparent that this clock gave a much better performance than any previous clock. In conjunction with W. Bowyer, who was in charge of the time service at Greenwich, Jackson studied the performance of the clock. The dependence of its rate on temperature and pressure was determined. He showed that the optimum pressure at which the free pendulum should be maintained was 18 mm, as the change in the arc of vibration caused by a change of pressure then resulted in a change of rate that was almost exactly compensated by the change of rate resulting from the change in air resistance. He found that most of the irregularities in the performance of the clock could be explained by the fact that sidereal time, which is affected by

nutation, is not uniform. This was the first time that a clock was found to be more uniform than sidereal time. It led to the introduction of mean sidereal time, freed from the effect of nutation, in time-keeping. Jackson investigated the possibility that it might be possible to use the Free Pendulum clocks to investigate the irregularities in the rate of rotation of the Earth but concluded that for this purpose the clocks were not sufficiently accurate.

An extensive piece of work undertaken by Jackson at Greenwich in collaboration with H. Knox-Shaw at the Radcliffe Observatory, Oxford, was the reduction of the observations made during the years 1774–1798 at the Radcliffe Observatory by Thomas Hornsby, the Savilian Professor of Astronomy and the first Radcliffe Observer. Hornsby's observations were known to be of high quality for their epoch, but Hornsby had been so assiduous in observing that he could find no time for the reduction of the observations, of which no use had consequently been made. The purpose of the reduction was to provide a check on the accuracy of the fundamental star system in use in the 20th century. The ephemerides in the Nautical Almanacs of the epoch were not of the required accuracy. Jackson undertook the task of computing, from Newcomb's Tables of the Sun, the positions of the Sun for every Greenwich Mean Noon and every Oxford Apparent Noon for the years 1774–1798, and the apparent places of the stars from the best tables available. Knox-Shaw, assisted by W. H. Robinson, used the observations to determine the errors of the instrument, apply the necessary corrections, and deduce the apparent places of the objects observed. The positions of the planets from Venus to Saturn were computed by A. C. D. Crommelin and B. F. Bawtree. The investigation proved that the motion of the equinox adopted by Newcomb and the proper-motions in the Boss Preliminary, General Catalogue were substantially correct. Jackson undertook the comparison of theory and observations for Mercury, and verified the motion of the perihelion of Mercury adopted by Newcomb, which is in accordance with the motion required by generalized relativity theory.

In 1933 Jackson was appointed H. M. Astronomer at the Cape, in succession to H. Spencer Jones, who had succeeded Sir Frank Dyson at Greenwich. The main programmes of work at the Observatory had been laid down. The Cape Astrographic Zones $-40°$ to $-52°$ had been rephotographed and the plates measured against the original plates for the derivation of proper motions. The results were published by Jackson in two volumes giving the positions and proper motions of some 41,000 stars; the introductions to these two volumes contained a detailed discussion of the data and of the distribution of the stars. The results were summarized in a paper in *M.N.*, **98**, 491, 1938. An extensive programme of stellar parallax determinations had been commenced in 1926, in collaboration with the Yale Southern Station in Johannesburg. At that time, there were few reliable determinations of parallaxes of southern stars. The Yale programme included the brighter stars of the southern sky; the Cape programme included mainly stars with appreciable proper-motions. Some 400 parallaxes had been published before Jackson was appointed to the Cape. He took a large part in this programme, particularly during World War II when the staff of the Observatory was much reduced. He took over the selection of the stars for observations and took the first few plates of each star, so as to determine the exposure time required to photograph suitable companion stars and the appropriate opening of the occulting shutter for the parallax star. He took a large share in the observa-

tions, obtaining as many as a thousand plates a year, and in the measurements and reductions. Between 1935 and 1950 four volumes of the Cape Annals were published, giving details of the measurements and of the derived parallaxes of about 1,600 stars.

Shortly before Jackson was appointed to the Cape, the determination of the positions of stars south of −30°, by means of photography with a wide-angle lens, had been commenced and the first zone, −30° to −35° had been photographed. The work of observation continued all the time he was at the Cape and, by the time he retired in 1950, all the zones to −80° (except the Cape Astrographic Zones −40° to −52°) had been photographed, the positions of the comparison stars observed with the transit circle, the measurement of the plates completed to about −68°, and the results for two zones prepared for publication. The plans included the determination of the magnitudes of the stars and for this purpose a Schilt photometer had been obtained. This part of the programme had not been started when Jackson arrived at the Cape. On the appointment of R. H. Stoy as Chief Assistant, the photometry programme was entrusted to him and as a result the photometry of southern stars, which had been in a very unsatisfactory state, has now been established on firm foundations.

During Jackson's tenure of the post of Chief Assistant at Greenwich he took part in three expeditions for the observation of total eclipses of the Sun. The eclipse of 1927 June 29 was observed at Giggleswick, Yorkshire. The weather conditions for this eclipse, the first since the time of Halley in which the track of totality had crossed England, were generally unfavourable, but at Giggleswick the sky was clear; the totality was short and the Sun was very low, but photographs of the corona were obtained. Jackson was in charge of expeditions to observe the total eclipses of 1929 May 9 at Alor Star, Malaya, when observations were spoilt by thick cloud, and of 1932 August 31 at Parent, Quebec, when clouds prevented spectroscopic observations with a slit spectroscope. Plans had been prepared for an expedition from the Royal Observatory, Greenwich, to Calvinia, Cape Province, to observe the total eclipse of 1940 October 1, the programme being the determination of the displacement of stars in the vicinity of the Sun predicted by Einstein. The outbreak of World War II made it impossible to send a party from Greenwich, but the equipment was sent to the Cape and used by Jackson. The eclipse was observed in a clear sky, but the definition proved unfortunately to be very poor; the images of the stars were in consequence too diffuse to permit of a satisfactory determination of the displacement.

Jackson was elected a Fellow of the Society in 1913. He served as Secretary from 1923 to 1929, and as President from 1953 to 1955. He was awarded the Society's Gold Medal in 1952. He was elected a Fellow of the Royal Society in 1938. On his retirement from the Cape in 1950 he was made a Companion of the Order of the British Empire. He then returned to England and made his home in Ewell, Surrey. He died on 1958 December 9 after a brief illness. In 1920 he married Mary Beatrice Marshall, who survives him. They had one son who died shortly after birth.

H. SPENCER JONES.

JACK GORDON MILLER was born in Russia in a village about 200 miles north of Odessa in 1890 November. His original name was Pinchas Mogilvsky.

In 1904 he migrated to England and joined a sister who was living in London. He became apprenticed to a firm of electrical engineers and during World War I he worked as draughtsman and then designer to Cubitt and Company being responsible for the electrical control gear on the large cranes which the Company manufactured.

In 1913 he married Edith Emilie Draphin, a concert pianist. After World War I Miller joined his father-in-law in the wholesale tobacco business and later set up on his own. He conceived the idea of opening tobacco kiosks on railway stations and his first kiosk was built at Covent Garden underground station, he himself carrying out most of the actual construction work. Although this first venture was not entirely successful, Miller persevered with his scheme and in a short while the idea met with popular support and his Company expanded. When his nephew-in-law Yehudi Menuhin came to England, Miller and his wife helped in many ways to launch the young violinist on his public concert career.

For many years Miller had a strong interest in astronomy and joined the British Astronomical Association in 1933. He was particularly interested in solar phenomena and he observed the total solar eclipses of 1948 May and 1954 June. His own observations were carried out with a coudé refractor of 9-inch aperture. He published papers on Newtonian gravitational theory and on the formation of the planets in the *Journal of the British Astronomical Association*.

He was well-known to many astronomers, both professional and amateur. Miller was a generous companion and had a strong desire to assist the furtherance of astronomical research. He purchased for the Society the National Geographic Society/Palomar Observatory Sky Survey, and a cabinet in which to keep it. He also gave the furnishings for the room in which the atlas is now housed on the Society's premises.

Miller was elected a member of the National Liberal Club in 1933 and was for twenty years a member of the Eccentric Club. His wife died in 1951 and he is survived by a son and daughter. He was elected a Fellow of the Society on 1953 January 9 and died on 1958 June 15.

COLIN A. RONAN.

WALTER MOSS was born in Leeds in 1878. He received his early scientific education at the High School there, now the Cockburn High School. After a period as assistant in its chemical laboratories he proceeded to the Royal College of Science, South Kensington, studying physics under Sir Arthur Rucker and chemistry under Sir William Tilden. He entered commercial life for a short time but in 1902 returned to South Kensington to the Solar Physics Observatory, as a junior assistant observer under Sir Norman Lockyer, working mainly with the spectroheliograph. In 1913 he moved to Cambridge, when the Solar Physics Observatory was transferred there, and was placed under Professor H. F. Newall. He became a senior assistant observer in 1929, holding that post until his retirement in 1945. He was for a time during World War II the senior member of staff in residence in Cambridge and under war time regulations he continued to serve for two years after reaching the normal retiring age.

His published papers were on the development of solar flares and prominences and on the relative intensities of hydrogen and helium lines in the spectra of prominences. His main contribution to solar physics was a study of the distribution and movements of solar prominence areas during a complete sunspot cycle.

He was elected a Fellow of the Society on 1911 January 13. He died on 1958 December 14, leaving a widow, a son and two daughters.

F. J. M. STRATTON.

CHARLES WILLIAM DYSON PERRINS was born on 1864 May 25 of a family of retail chemists in Malvern who had amassed a fortune through the sale of their famous " Worcester Sauce ". After an education at Charterhouse and Queen's College, Oxford, and four years as an officer in the Highland Light Infantry, Dyson Perrins joined the family business. He took an active part in the civic life of Worcestershire, being Mayor of Worcester (1897) and High Sheriff of Worcestershire (1899), and in education, being a Life Governor of Birmingham University and a member of the Council of Malvern College. By 1900, he had begun to acquire a collection of illuminated manuscripts and early woodcut books that was later to become unique among the private collections of Great Britain. His interests were varied, and he became a recognised authority on the making of Worcester china. Indeed, the preservation of this craft during the difficult between-war period was due to Dyson Perrins's benefactions. After World War II, his collection of books and manuscripts was sold to provide for the equipping and expansion of the Worcester china works. He was elected a Fellow of the Society in 1895 and with his death, on 1958 January 29, the Society has lost one of its few remaining personal links with the nineteenth century.

JOHN BENSON SIDGWICK, who died on 1958 July 13, was born in Scarborough on 1916 February 10 and was a great-great-nephew of Henry Sidgwick, the Cambridge philosopher. Educated at Clifton and Peterhouse, Cambridge, he was by nature restless and was slow in adopting any fixed profession. Further unsettling influences in his life were the outbreak of the Second World War, when he was 23 years old, and the untimely death of his young wife in 1944. In the course of his regrettably short life he found occupation, at one time or another, in a publisher's office, in newspaper work, broadcasting, running a nutria farm, working in a Chinese bakery and on a pearling lugger, and in hitch-hiking all over the United States and Canada.

Probably the most stable thing in his life was his love of literary work; and it is as a writer that he will chiefly be remembered by astronomers. In all that he wrote he managed to combine accuracy in detail with lucidity of expression, and his three popular treatises—*The Heavens Above*, *The Life of William Herschel* and *Introducing Astronomy* were well above the average standard of this class of book.

Amateur astronomers in particular will long be grateful to Sidgwick for two practical guides—*Amateur Astronomer's Handbook* and *Observational Astronomy for Amateurs*. His success in both these works is particularly remarkable for the fact that they must both have been written largely " from an armchair "; for, although he himself possessed a small telescope, he had never settled down long enough to accumulate the personal experience that many might have considered necessary as a preliminary to such an ambitious undertaking.

He was elected a Fellow of the Society on 1943 March 12.

W. H. STEAVENSON.

PROCEEDINGS OF OBSERVATORIES

Royal Greenwich Observatory

(Director, Dr R. v. d. R. Woolley, O.B.E., F.R.S., Astronomer Royal)

Meridian department

Cooke Transit Circle.—The usual programme of observation of the Sun, major and minor planets, and of stars for clock- and azimuth-error, was maintained throughout the year. Observations of members of the solar system number:—

Sun	79	Jupiter	19	Ceres	7
Mercury	9	Saturn	24	Juno	3
Venus	35	Uranus	15	Vesta	3
Mars	27	Neptune	13		

The number of transits observed, including these, total 20,814, the majority being of AGK3 Reference Stars and stars in the FK3. Stars in FK3 (Supp), in Blaauw's list of stars needing observation for use in galactic research, and stars in this and other observatories' P.Z.T. programmes, are also under observation. The Observatory's commitments under the AGK3R programme are large and this total of nearly twenty-one thousand observations is very gratifying. It is the result of a sustained effort on the part of the T.C. observers.

The redesigned electronic apparatus for recording transit times directly on to Hollerith punched cards (EPIC) is now functioning more reliably; so also is the digitizer attached to the photo-measuring machine used for punching the data from the circle reading camera films.

In spite of the loss of records of some 2,000 observations (not included in the above total) due to failures of these and other subsidiary apparatus, which had to be brought into regular service whilst really in the prototype stage, the record total of transits observed in one year is due in no small measure to these labour- and time-saving devices.

Photographic Zenith Tube.—From 1958 January 1 the number of stars in the P.Z.T. working list was reduced by half to 128 and observations were restricted to two plates per night. (During the previous two years, when the main objective was the derivation of improved star places, observations were made throughout the hours of darkness.)

During 1958 the number of stars observed was 1788 on 171 plates. The latitude and time results have been sent regularly to the Bureau de l'Heure in Paris and the Office of the International Latitude Service in Turin. The latitude results have been incorporated in the Service International Rapide (S.I.R.) which publishes co-ordinates of the pole with the minimum delay, for the correction of time observations made at all observatories which maintain time services. They will be used in due course in the reduction of the declinations observed with the Cooke Transit Circle. The time results are used in the establishment of the Observatory Time Service.

When the currently adopted star places were derived from observations made during 1956 and 1957 a closing error of $0''.5$ was found in declination. This closing error is confirmed by the observations made during 1958.

Astrolabe.—Installation of the O.P.L. Astrolabe is proceeding.

Time Service.—Observations made with the P.Z.T., and corrected for the effects of polar variation and annual fluctuation, have been used for the assessment of the performance of the quartz clocks employed in the control of the time signals. Two additional clocks, 17 and 18, have been installed during the year; these incorporate the quartz rings 17 and 31 formerly used at Abinger in the standards E5 and C6. By the continued co-operation of the National Physical Laboratory and the Post Office Radio Branch Laboratories, the standards at these establishments are also made available for the time service. Information is received regarding the caesium standard at the National Physical Laboratory. The divergence of about 5 parts in 10^9 per year which had apparently continued over some two years was not evident during 1958 in the comparisons between the caesium frequency and the time scale defined by the astronomical observations made with the Herstmonceux P.Z.T.

Reception and measurement of radio time signals has continued; the aerials have been completed during the year. Publication of results has been subject to some delay, but the position is improving.

The rhythmic form of radio time signal, used by the Royal Observatory for the International Time Signals since their inception in 1927, is now regarded as obsolete, and it was decided to discontinue these signals from 1958 July 1. The mean-time signals of the "English System", introduced in October 1950, are being continued. In November the reserve transmitter, Criggion GBZ, which had been used for the 1000 and 1800 radio time signals for the past two years, was replaced by the main transmitter, Rugby GBR, which had been extensively overhauled.

Astrophysics.—Regular observing with the Yapp 36-inch reflector and one-prism spectrograph (giving a dispersion of 120 A/mm at Hγ) was begun at Herstmonceux on 1958 September 9. Numerous tests on stars in Wilson's catalogue have shown the spectrograph to be suitable for the determination of radial velocities with a probable error of about ±3 km/sec.* The following programmes are currently being carried out :—

1. Improvement of radial-velocity data for variable-velocity stars in the ξ Persei association to improve our knowledge of the kinematics of this system. Current results suggest that two of the stars (22951 and 14640) are β Cephei variables, and there may be others. With baked Kodak (U.K.) IIaO plates it is possible to reach a B star of magnitude $6^m{\cdot}0$ in about 1 hour on a normal clear night.

2. Improvement of radial-velocity data for A stars in Oort's north galactic polar zone by (*a*) extension of measurement to faint stars not in Wilson's catalogue, and (*b*) systematic study of spectroscopic binaries for which orbits are not yet available. With Kodak OaO or 103aO plates, it is possible to reach a $6^m{\cdot}5$ A star in about 1 hour on a normal clear night.

3. Luminosity classification of Ko stars from the HD catalogue in search of dwarfs for inclusion in the Astrometric programme.

In addition to the plates obtained at Herstmonceux (amounting to some 300 spectra in 1958), the Department has been concerned in the measurement of spectra obtained at Mt Wilson by the Astronomer Royal and at the Radcliffe Observatory, Pretoria, by P. A. Wayman. The Mt Wilson observations consist

*For B and A stars if advantage is taken of the high ultra-violet transmission of the optics to measure all the Balmer lines (except H9) up to H12 (B stars) or H15 (A stars).

of 140 plates of 50 stars from Gliese's catalogue of stars within 20 pc. taken with the Xf grating-camera combination (80 A/mm) on the 60-inch telescope. So far 50 spectra of 24 stars (mainly K dwarfs) in Wilson's catalogue have been measured in order to determine standard wavelengths. These come out with probable errors of only a few km/sec and without any systematic difference between measurers; also the wavelengths agree with those given by R. M. Petrie, although there is not complete agreement with Petrie as to which lines are the most reliable. However, serious systematic differences (amounting in extreme cases to 10 km/sec) have occasionally been found between different plates of one star. The Pretoria plates consist of some 200 spectra of solar-type stars taken with the Radcliffe 2-prism c-camera combination (59 A/mm) in an extension to the southern sky of Paddock and Moore's programme; and half of these have now been measured. The probable error, of the order of 1·5 km/sec for one plate, agrees well with the differences between measurers.

Finally, in order to extend the range of magnitude accessible from Herstmonceux with adequate dispersion for velocity and spectrophotometric measurements, a new grating spectrograph is being designed for the 36-inch telescope. This should be ready about the end of 1959.

Astrometry

30-*inch reflector*.—Comparison between the visual images of a close double star at an *ad hoc* Newtonian focus and at the Cassegrain focus has shown that the performance of the telescope at the Cassegrain focus could be improved by re-figuring the secondary mirror. The work has been entrusted to Sir Howard Grubb, Parsons & Company.

13-*inch refractor*.—This telescope was brought into use in January, a new synchronous motor replacing the previous gravity drive. During the dark of the Moon the instrument is being used to secure second-epoch plates of fields containing:

(*a*) the " expanding associations " of B stars in Lacerta;
(*b*) the similar aggregate in Perseus; and
(*c*) such of the red variables in Plaut's list (adopted at the Groningen conference) as appear on the Greenwich astrographic plates.

First-epoch plates for (*a*) have been kindly lent by the Directors of the observatories at Helsinki, Catania and Hyderabad. The whole area has now been re-photographed at least once, and measurement is proceeding. The only early plates available for (*b*) cover only part of the field; they are in the Oxford zone, all the Carte-du-Ciel plates of which are now stored at Herstmonceux by arrangement with the Director of the Oxford University Observatory.

For the fortnight around full Moon, the Markowitz moon camera is attached in place of the ordinary breech end. Progress was disappointing during the summer: with a low Moon near full the sky brightness is usually such that only bright stars can be distinguished from the background fog, and these are fewer than are necessary for the precision required in locating the Moon's position. Even at the quarter phases successful plates require a carefully-chosen combination of aperture, emulsion and exposure time and a transparent sky.

26-*inch refractor*.—Erection was completed in June. A counterweight replaces the 30-inch reflector tube which shared the mounting when the telescope

was at Greenwich. The rising floor at the new site has proved reliable in use and a substantial convenience in the rapid handling of the telescope.

The main programme continues to be the measurement of trigonometric parallax; the region of the sky covered is, however, no longer confined to the Greenwich astrographic zone ($+90°$ to $+64°$) but extends over the whole N. hemisphere. This involves using the tube over a range of altitudes considerably greater than at Greenwich, and some puzzling anomalies in the behaviour of the images have caused a good deal of trouble. They were finally traced to a slight movement of the flint component of the object-glass within its cell, a movement that does not occur when the telescope is confined to the neighbourhood of the zenith, as at Greenwich. The cell has been modified to prevent this and there has been no recurrence.

The new working catalogue comprises:

(*a*) stars in Gliese's catalogue of stars believed to be within 20 pc. for which no trigonometric parallax is yet known; and

(*b*) stars in the *Yale Parallax Catalogue* for which the parallax, if $>0''{\cdot}070$, depends on one determination only; or for which determinations at more than one station are discrepant by $>0''{\cdot}040$.

Insofar as there are then gaps in the catalogue, these are filled from:

(*c*) stars in the pre-war working catalogue (largely white dwarfs and Ko stars of moderate proper motion in the Greenwich astrographic zone).

Key plates for these fields are currently being secured.

28-inch refractor.—The double star measures begun in 1957 November were continued until January 23. During the period January 1–23, nine measures were made of five stars on three nights.

During the period January 23–July 10, the telescope was not available for double star observations. In the latter part of this period the telescope was out of service because of modifications to the dome; the earlier part was devoted to a short test of the telescope's photographic capabilities. With the combination of yellow filter and orthochromatic emulsion most suited to the colour curve, it was found that the telescope, though suitable for photography, was definitely slower than the 26-inch refractor.

Double star observations were resumed on July 11 and continued to the end of the year. 304 observations were made on 68 nights—the number of observations for various separations is given in the following table.

$d<0''{\cdot}5$	$0''{\cdot}5\leqslant d<1''{\cdot}0$	$1''{\cdot}0\leqslant d<2''{\cdot}0$	$d>2''{\cdot}0$
14	71	123	85

In addition 11 observations were made of position angle without separation, mainly of close pairs.

For wide pairs the filar micrometer was mainly used; for close pairs it was found best to measure position angle with the filar micrometer and separation with the comparison image micrometer. Some inconclusive tests were also made of a Sinton eyepiece interferometer by Mr Holden of Manchester University.

By the beginning of December it was felt that sufficient experience had been gained to embark on a systematic programme. 440 stars in relative motion were chosen, mainly between 30 and 90 degrees of the North Pole and with the primary

brighter than the eighth magnitude. The aim in compiling this list was to include all stars which might be measured reliably with this telescope but would seriously extend a smaller.

Dr D. V. Thomas was in charge of the telescope until November 23 and Mr D. H. P. Jones after that date. The majority of the measures were made by the Astronomer Royal, Mr Symms, Dr Thomas, Mr Jones and Mr Candy. Occasional measures were made by Mr Harding, Mr Alexander, and Mr Gottlieb of the Mt Stromlo Observatory.

Solar department.—Routine photographs of the Sun in white light were obtained with the 4-inch photoheliograph on 280 days during the year. Negatives in duplicate up to September 30 have been received from the Royal Observatory, Cape of Good Hope. Two days, viz., May 6 and September 29, were unrepresented in the Herstmonceux—Cape—Kodaikanal series.

As part of the Royal Greenwich Observatory's contribution to the International Geophysical Year scheme for studying sunspot group development, one or two additional plates were taken daily, when justifiable, at intervals of two or three hours. A register of all photographs has been sent to the Federal Observatory, Zürich, as well as the sunspot numbers derived from the Herstmonceux plates.

Measurement and reduction of the combined series was carried up to 1957 December 31.

Summary tables of mean areas and mean latitudes of sunspots for 1956 and subsequent years will be published in Royal Greenwich Observatory Bulletins instead of in the *Monthly Notices*.

On 249 days photographs in Hα light on 35 mm film were taken with the Levallois-Lyot birefringent filter attached to the 6-inch Newbegin refractor. Negatives of disk and limb features have been sent fortnightly to the Fraunhofer Institute for the compilation of daily maps.

From March 21 to September 21 the I.G.Y. programme included a daily solar flare patrol between 14^h00^m and 16^h00^m U.T., the Sun being photographed at intervals of not less than three minutes. Owing to unfavourable weather, the coverage for 1958 amounted to 36 per cent, against 45 per cent during the previous summer.

Information on flares, surges and prominences has been transmitted, with observing times, to the appropriate World Data Centres.

Only 30 flares of importance class $\geqslant 1$ (i.e. approximately one third of the 1957 total) were observed with the birefringent filter and the spectrohelioscopes, although 152 enhancements of atmospherics (S.E.A.s.) on 27 kc/sec were recorded.

To facilitate the distribution of current information, a Solar Activity Circular has been issued monthly throughout the year to individuals and institutions. This contains brief details of sunspots exceeding 500 millionths of the visible hemisphere in area, sunspot numbers, solar flares and S.E.A.s.

Nautical Almanac Office.—The 1959 editions of the annual publications of the Office, other than the *Nautical Almanac* which was published in 1957, and the four-monthly parts of the *Air Almanac* for 1958 September to 1959 April were published during the year. No change has been made in the content of these volumes.

The volume of *Planetary Co-ordinates for the Years* 1960–1980 and the booklet *Subtabulation* were published early in the year.

In addition to the routine of preparation of the ephemerides, the work of the Office has been mainly directed towards the full utilization of the small electronic computer, to be installed in April, and to the compilation, jointly with the U.S. Nautical Almanac Office, of the *Explanatory Supplement.*

Royal Observatory, Edinburgh

(*Director, Professor H. A. Brück, Astronomer Royal for Scotland*)

Stellar work. 36-inch reflector.—82 two-prism and 199 one-prism spectrograms of early-type stars have been secured during the year.

The photometric analysis of the spectra of sixteen stars of types O6–Bo by Dr R. Wilson has been published as Volume II, No. 3, of the series of *Publications of the Royal Observatory, Edinburgh.* This volume contains measures of the equivalent widths of thirty-five lines in the visible region of the spectrum.

An investigation of certain broad emission features in O stars has developed from this work, and a paper, originally written by Dr Wilson for presentation at the Liège Astrophysical Colloquium, has been published as *Edinburgh Communication* No. 16.

The analysis of the spectra of twenty stars of MK type B2 by Dr H. E. Butler and Mr H. Seddon has been published as Volume II, No. 4, of the *Edinburgh Publications.* This paper contains equivalent widths of sixty-nine absorption and emission lines.

The measurement and reduction of the spectra of twenty-seven stars of type B3 which had been started in 1957 has been completed. More than 2,500 measures were made in each of 140 spectra. The results became available in December, and their analysis is now in progress.

Measurement and reduction of seventeen spectra of B5 stars has been started, and it is anticipated that the analysis of these and of thirty-four remaining B5 spectra will be completed and be ready for publication by the summer of 1959. The publication of these B5 spectra is to conclude the general spectrophotometric programme of early-type stars which was begun at Edinburgh in 1938.

A comparison of the spectrophotometric techniques used at Edinburgh with those in use at the Dominion Astrophysical Observatory has been made by Dr Wilson during his stay at Victoria as a Research Fellow. Seven Edinburgh spectrograms of 9 Cam (O 9·5 Ia) were measured and reduced with the semi-automatic Victoria equipment. In the case of normal spectral features there was good agreement, and no systematic differences were found between the Victoria and Edinburgh measures. The strength of the Edinburgh method came out clearly in the case of broad shallow features such as interstellar bands which were not revealed by the Victoria measurements.

In May, 1958, Mr Seddon's photoelectric spectrophotometer, which has been mentioned in last year's report, was attached to the telescope and used on the Hγ region of the spectra of ϵ U Ma and ζ U Ma. These were the only two bright stars of sufficiently early type in the night sky at the time of observation. The performance of the equipment has been satisfactory; further observations are to be made in due course.

16-inch Schmidt telescope.—Dr V. C. Reddish and Mr J. H. Reid have continued their three-colour photometry of galactic clusters. Fifty-one plates

have been obtained during the year. In a search for small-amplitude variables in old Population I clusters, plates of NGC 7789 were obtained on eight nights.

In *The Observatory*, **78**, 247, 1958, Dr Reddish has drawn attention to certain correlations found between measures of *B* and *V* magnitudes of cluster stars both in photographic and photoelectric observations.

Part of the Schmidt telescope was dismantled at the end of the year so as to allow the construction of a new plate-loading arrangement which has been designed by Messrs Cox, Hargreaves and Thomson, Ltd.

Solar work.—Disk drawings of the Sun in white light were obtained on 110 days, and Hα observations were made with the spectrohelioscope on 120 days. I.G.Y. flare patrols were carried out up till September 30 on all fine days (11^h00^m–13^h00^m in winter, 13^h00^m–15^h00^m in summer). Thirty-four flares were recorded during 177 hours of observation: one of class 3, nine of class 2, eighteen of class 1, and six of class 1^-.

Solar activity remained at a consistently high level throughout the year. The monthly means of the (provisional) Zürich relative sunspot numbers (R) exceeded 200 in the months of January (203), August (204) and September (201). Flare activity, judged by the number of recorded sudden ionospheric disturbances, was greatest in March (41) and April (26). The two recorders which give the integrated level of radio atmospherics on frequencies of 24 Kc/s and 30 Kc/s were in continuous operation: the number of sudden enhancements of atmospherics (193), indicating ionization of the D-region caused by flares, may be compared with those in previous years as follows :—

Year	1951	1952	1953	1954	1955	1956	1957	1958
S.E.A's	81	22	7	0	33	107	206	193

The direct recording Askania H-magnetograph was in operation throughout the year for the recording of solar flare effects (crochets) and magnetic storms.

Dr M. A. Ellison visited the Royal Observatory, Cape of Good Hope, from February 21 to April 9 to supervise the installation of the Lyot Hα Heliograph. This instrument was constructed for the Admiralty by the firm Societé d'Etudes et de Construction d'Appareillages Scientifiques et Industriels of Bordeaux and was financed by a grant from the British National Committee for the I.G.Y. After erection and testing, in the building prepared to receive it, the Heliograph was brought into daily operation on March 10. A description of the instrument has been given by Dr Ellison in *Nature*, **182**, 624, 1958 (*Edinburgh Communications* No. 17). It is entirely automatic in operation and takes photometrically calibrated exposures in Hα of the solar disk at 1-minute intervals during a 7-hour period each day. Every eleventh exposure is increased five times so as to record limb prominences.

The films were developed at the Cape and sent to Edinburgh each week for analysis. In the first ten months of operation film runs were obtained on 230 days out of 295 possible days, and 694 flares were recorded: four of class 3, forty-two of class 2, two hundred and fifty-six of class 1, and three hundred and ninety-two of class 1^-. The data on flares and active prominence regions were communicated monthly to the three World Data Centres of the I.G.Y. We owe this remarkable coverage to the co-operation of Professor R. H. Stoy and his staff at the Royal Observatory of the Cape: it has made a great contribution to the completeness of the solar patrol during the second half of the I.G.Y.

The Kipp star actinometer was adapted for use with the heliograph films; techniques were developed for flare photometry, and Hα light curves for six flares were plotted. By arrangement with the Royal Society and the Admiralty the work connected with the analysis of the heliograph results was transferred to Dunsink Observatory from November 1.

During the year spectrum plates in the three regions Hα, Hβ and Hγ were obtained by Mr J. H. Reid of selected plages, using the combined spectrohelioscope and spectrograph. Nine regions on six sets of plates have been measured. Intensity measures of plate regions recorded on the Lyot Heliograph films in Hα have also been made. A comparison of the filter intensity measures has still to be completed. In view of the present existence of several automatic Hα heliographs at Observatories in climates more favourable to observation of solar activity than that of Edinburgh, it has been decided to discontinue spectrohelioscope observations at the Royal Observatory.

Other work.—In the first part of the year some time was spent by Dr Butler, Mr Ramsden, and other members of the staff on the observation or attempted observation of artificial satellites. In the case of Dr Butler this led to studies of the possible use of " Skylark " rockets for astronomical observations.

Dr Reddish has been engaged in further discussions of the rate of formation of stars (*The Observatory*, **78**, 198, 1958) and of the luminosity function of M67 (*The Observatory*, **78**, 255, 1958). He has also attempted a preliminary analysis of the physical evolution of five local galaxies.

Dr Wilson, after his return from Victoria, has worked on the completion of a paper in which he predicts that the law of interstellar reddening varies with interstellar polarization, and that the ultra-violet extinction becomes relatively greater in regions of low polarization, such as that of Cygnus. Dr E. A. Baker, retired Principal Scientific Officer, has made use of the large material of photometric calibrations of the Edinburgh spectrograms for further tests of his theory of photographic action.

Time service.—The mean time clocks Riefler 258 and Leroy 1230 have been in use throughout the year to provide the control currents for the local time service, for the firing of the time gun from Edinburgh Castle and for the dropping of the time ball from the Nelson Monument on Calton Hill.

Seismology.—Building operations in the basement of the Observatory affected the working of the Milne-Shaw seismograph on three days. Apart from this the instrument has functioned continuously throughout the year.

Our thanks are due, as in former years, to Mr E. Tillotson for undertaking the reduction of the seismograms and for answering correspondence relating to them.

Building.—In order to allow for an extension in the fields of work and an expected increase in staff, some building operations have been started in the Observatory with the aim to enlarge and improve the present office, laboratory and general accommodation. Work has begun on two new air-conditioned darkrooms and an electronics laboratory and plans have been drawn up for the construction of new workshops to the west of the main building and on the site of the present transit house. It is expected that the various new facilities will be completed early in 1960.

Conferences.—Professor Brück, Dr Ellison and Dr Reddish took part in the Tenth General Assembly of the I.A.U. in Moscow. Dr Ellison also attended the Fifth Assembly of the special Committee for the I.G.Y.

Visitors.—Professor Redman and Dr Blackwell of Cambridge have been visiting speakers to the Observatory Colloquia. The General Secretary of U.R.S.I., Col. Herbays of Brussels, and a party of U.R.S.I. members, visited the Observatory on the occasion of the Edinburgh meeting of the I.G.Y. Committee of U.R.S.I. Overseas visitors included Dr Brown (Melbourne), Professor Carpenter (Tucson, Arizona), Professor Edmondson (Bloomington), Dr Herzberg (Ottawa), Dr Petrie (Victoria) and Professor Stoy (Cape).

A party from the Deutsches Geodätisches Forschungsinstitut, Munich, visited the Observatory in May and June to make gravity measurements.

Staff.—There have been several changes in the staff. Dr Ellison resigned his post of Principal Scientific Officer on October 31 to take over the Directorship of Dunsink Observatory. He was followed to Dunsink by Mr J. H. Reid, Experimental Officer, who left the Observatory at the end of the year. Dr R. Wilson, Senior Scientific Officer, who returned from Victoria on May 1, took up an appointment as Principal Scientific Officer at Harwell on December 1. These vacancies had not been filled by the end of the year.

On October 1, Mr Fazal Ahmed, M.Sc., joined the Department of Astronomy as a Research Student.

Royal Observatory, Cape of Good Hope

(*Director, Professor R. H. Stoy, C.B.E., H.M. Astronomer*)

New equipment.—A Lyot Hα Heliograph built by the Societé d'Etudes et de Construction d'Appareillages Scientifiques et Industriels of Bordeaux arrived at the end of February and was brought into routine use by the middle of March. This instrument, which was provided by the British National Committee for the International Geophysical Year, is being operated in co-operation with Professor Ellison. It is the first new major equipment to be installed at the Cape since the Victoria Telescope was given to the Observatory over sixty years ago.

In January, as a result of representations made to the Admiralty over several years, a contract was signed with Sir Howard Grubb, Parsons & Co. Ltd. for a 40-inch reflector to be delivered at the Cape in 1962. The instrument, which will have a normal English-type mounting, is intended to be used at either the prime or the Cassegrain focus. It will be fitted with an auxiliary reflector corrector system so that it can be used also for wide field photography. The housing for it will be situated just north of the present Main Building and will be a simple utilitarian brick building supporting the dome which used to cover the 36-inch Yapp Reflector when it was mounted in Greenwich Park.

Gill Reversible Transit Circle.—The observations for the "Second Cape Catalogue for 1950.0" were continued throughout 1958 and finished early in 1959. The working list contained approximately 7000 stars and included all FK3 stars south of −30°, all GC stars brighter than magnitude 8·5 between −30° and −52° and between −80° and −90° and a selection of stars south of −80° to serve as standards for the reduction of photographic observations. The stars have, in general, been observed eight times, four in each position of the instrument. The reduction of the observations has been kept well up to date and it is anticipated that the resulting catalogue will be completed before the end of 1959. During 1958 a total of 9818 transits were observed. This includes 381 observations of stars made during the daytime and 382 observations of bodies in the solar system.

The next working list is being prepared. It is to be in five sections. The first section will contain stars south of +30° from the fundamental catalogues FK3, FK3 Supp and FKSZ while the other four sections will contain relatively faint stars between −30° and −40°, −40° and −52°, −52° and −64°, −64° and −90° specially selected to serve as standards in the reduction of photographic plates. Provisional selections for the first three of these zones have been made and circulated to interested parties as Cape Mimeograms Nos. 7, 8 and 9. The first section containing the fundamental stars will be observed continuously throughout the life of the catalogue while the other stars will be observed by zones beginning with those between −40° and −52°. It is intended to strengthen the meridian places of these zone stars by concurrent photographic observations.

Cape Photographic Catalogue for 1950.0.—Work on this project proceeds steadily, the position at the end of 1958 being as follows: the catalogue was published as far as −56°; in the printer's hands as far as −64°; positional measures complete to −76°; photometric measures complete to −72°. About one quarter of the astrometric plates for the zone −76° to −80° were measured. South of −80° the meridian and photographic observations are complete and the stars to be measured have been selected. The computation of the necessary standard coordinates is in hand.

Minor planets.—The routine observation at approximately ten-day intervals of ten selected minor planets has been continued. During 1958 the following observations were obtained :—

3.	Juno	7	18.	Melpomene	5
4.	Vesta	2	39.	Laetitia	12
7.	Iris	8	40.	Harmonia	10
11.	Parthenope	11			

The Markowitz Dual-Rate Lunar Camera.—A considerable amount of workshop time has been spent on adjusting the Markowitz Dual-Rate Lunar Camera and adapting it so that it can conveniently be put on and off the Astrographic Refractor. An old chronograph has also been rebuilt and adapted for use with it. After the apparatus had been adjusted, 42 plates were obtained. Four of these plates have been measured and reduced. The measures have been sent to the U.S. Naval Observatory, but no comment on them has yet been received. This programme, which was intended to be carried out during the International Geophysical Year, has now been suspended until there are definite indications that it will be carried out on the international scale originally envisaged.

Photoelectric photometry.—The photoelectric photometers attached to the various telescopes were kept in continuous use throughout 1958 by the Cape staff and by a more than usual number of visitors to the Observatory. Because of the favourable conditions during the winter it was possible to finish off the E region programmes which were begun several years ago to provide adequate and reliable standard sequences for the southern hemisphere. The resulting standard system for stars brighter than magnitude 8·6 SPg is set out in Cape Mimeogram No. 5. The definitive results for the fainter stars are still being worked up.

The Victoria Telescope was used partly for the E region programme and partly for making three-colour observations of a miscellaneous list of stars. This list includes all the stars being observed for radial velocity at the Radcliffe Observatory by the Greenwich and Cape observers, the stars in the Cape parallax programme which have not already been observed photoelectrically and other stars of special interest for which photometric data have been requested by various astronomers.

The 18-inch Reflector was used for three programmes, two of which were completed during 1958. These were the E region programme and the observation of the blue and yellow magnitudes of 213 stars which comprise the comparison sequences that have been used in the past for 19 bright southern cepheid variables and the long-period variable BL Telescopii. The third programme is the observation of the brighter southern stars as closely as possible on the *U, B, V* system by comparing them directly with the Johnson-Morgan standard stars near the equator. By the end of 1958 observations were complete for approximately three hundred stars, all of which had been observed at least four times.

The Astrographic Refractor was used for observing a few variable stars, for rounding off a series of blue-yellow observations of HR stars that was begun some years ago and for measuring the blue-ultraviolet colours of the HR stars that have already been observed in the blue and yellow.

The numbers of photoelectric observations made for the various observatory programmes during 1958 were as follows :

Victoria Telescope

General programme	2735
E region programme	366

18-inch Reflector

E region programme	1877
Comparison stars for variables	1205
U, B, V programme for bright stars	2112

Astrographic Refractor

Variable stars	316
HR *B–V* programme	69
HR *U–B* programme	2551

Photographic photometry.—During 1958 the measurement and reduction of the photometric plates for the −68° to −72° zone of the Cape Photographic Catalogue for 1950·0 were completed. Preparations for observing the remaining zones were commenced. As these lie south of −72° it has been decided to use the F regions at −75° for routine comparisons and, as a preliminary to the new programme, standard sequences are being chosen in these three areas and carefully tied into the general magnitude system defined by the nine E regions.

During the year 15 pairs of plates were obtained with the Photometric Cameras, 5 pairs being of the polar region and the remainder plates comparing the E and F regions. 39,826 images were measured with the modified Schilt photometer of which 35,546 on 50 pairs of plates were for the −68° to −72° zone programme.

The photometric measures of the brighter stars in the neighbourhood of the E regions which were made some years ago have been reduced to the magnitude system defined by Cape Mimeogram No. 5. The results have been set out in Cape Mimeogram No. 6 which gives the V and SPg magnitudes and the *B–V* and SCI colours for over 3000 stars including most of these brighter than visual magnitude 10·0. The introduction for this mimeogram has still to be prepared.

Part II of Volume 21 of the *Leiden Observatory Annals* which was published at the end of 1957 gives photographic magnitudes for 15,651 stars brighter than about magnitude 10·5 in the Kapteyn Selected Areas south of the equator.

A large number of these stars occur also in the Cape Photographic Catalogue for 1950·0. As the magnitudes given in both catalogues are new and independent determinations, it is of some interest to compare them for the stars in common. Such a comparison was made for approximately 1320 stars in the twelve Selected Areas at −60° (1). The results of this comparison were very satisfactory and inspired a feeling of confidence in the average quality and consistency of both these two extensive series of magnitudes.

Variable stars.—Mr R. P. de Kock continued his programme of visual observations of long period variable stars and in June made the 100,000th observation in this series which he began twenty-six years ago. During 1958 itself he made 6288 observations of 176 stars with the 6-inch telescope. He also kept a special watch on T Orionis and on two "flare" stars: 013418 UV Ceti and 203501 AE Aquarii.

Heliographs.—The Sun was photographed on 339 days with the old heliograph and the plates sent to Herstmonceux for measurement. The Lyot Hα Heliograph was run for an average of 5½ hours on every clear day after it was installed in March, the actual number of such days being 230 out of a possible 295. This average of 78 per cent is fairly high considering that it includes the whole of the winter period which is the normal cloudy season at the Cape. After development the films have been sent to Professor Ellison who has examined them and forwarded the appropriate data to the I.G.Y. Data Centres. 694 flares were detected of which 4 were of Class 3, 42 of Class 2, 12 of Class 1+, 244 of Class 1 and 392 of Class 1−.

Radcliffe section.—Once again most of the Cape and Greenwich observing time with the Radcliffe reflector has been devoted to the radial velocity programmes. The Cape programme contains about 300 stars, mostly nearby stars or stars with large proper motions. The Greenwich programme is in two sections. The first, which was virtually finished during 1958, consists of 120 A type stars in the region of the south galactic cap while the second includes 315 stars south of −21° with spectral types between Fo and M and HD photographic magnitudes between 8·5 and 8·6. The total number of radial velocity spectra obtained during 1958 was 1293 of which 314 have been sent to Herstmonceux for measurement. 1082 spectra have been measured and reduced in South Africa. An additional 18 spectra of planetary nebulae were obtained with the Cassegrain spectrograph and 35 spectra of planetary and extragalactic nebulae with the Newtonian spectrograph. 38 direct photographs of nebulae were also taken at the Newtonian focus. Dr Evans has measured and discussed 23 of the Cassegrain nebular spectra and 19 of the Newtonian spectra. He and Dr Wayman have provided radial velocities for five extragalactic nebulae whose velocities were not previously known (2). They have also given some consideration to the question of the formation of spiral arms in extragalactic nebulae by the action of radiation pressure on dust (3).

A second list of fundamental data for southern stars giving newly-determined radial velocities, magnitudes, colours and spectral types has been compiled. This list is an extension of that published in 1957 (4) and brings the number of stars for which new and completely independent data has been provided up to 500.

Guest investigators.—During the last three months of the year, the Victoria Telescope was partially placed at the disposal of the D.S.I.R. expedition. Mr Alexander of the Royal Greenwich Observatory was stationed at the Cape while

Dr Eggen and Dr Sandage paid periodic visits from Pretoria where they were working at the Radcliffe Observatory. Dr Sandage and Mr Alexander took a series of photographs in two colours of two variable stars fields in the Large Magellanic Cloud. This series is being continued throughout the Cloud season by Mr Alexander. Photoelectric standards will be established in these fields with the 74-inch Radcliffe reflector and two-colour light curves deduced for the variable stars. In a preliminary blinking of the plates, Dr Sandage has found approximately five new variables for every one previously known.

Dr Eggen has used the 18-inch Reflector to determine the extinction, in three colours, at $-15°$ and $-45°$, to carry the zero-point of the $(P, V)_B$ and (U, B, V) systems to the Large and Small Magellanic Clouds and to make three-colour observations of bright stars in the standard sequences he is setting up with the Radcliffe reflector. He also used the same telescope to make three-colour observations of southern dwarfs, subdwarfs and subgiants, while he used the Victoria Telescope to make three-colour observations of fifty main sequence stars of spectral type between Go and K5. Two dwarfs, HD 9847 and 14044, were found to vary with a range of 0·5 of a magnitude while a short period variation of very small amplitude was found in the combined light of the two equal components of 55 Eridani.

Professor W. Becker arrived at the beginning of November to spend about four months making three-colour photometric observations of selected galactic clusters in order to determine their distances. Most of this work will be photographic, but the photographs are to be reduced with the aid of photoelectrically determined sequences. By the end of December Professor Becker, who used the Victoria Telescope, had obtained 90 photographs and 146 photoelectric observations of the following clusters: NGC 1807, 1817, 2215, 2323, 2324, 2360, 2439, 2447, 2910 and 2925.

Mr R. V. Willstrop of the Cambridge University Observatories has used a special 4-inch telescope to compare the brighter stars at four wavelengths with a calibrated standard lamp and so to deduce the relationship between the conventional magnitude systems and the normal c.g.s. units of physics. He chose sixteen stars in a ring round the sky to use as standards and compared each with its neighbours on at least twenty nights. The calibrated lamp was compared with the standard star most nearly at the zenith at intervals of from two to three hours. An additional two hundred stars were observed in the intervals between the comparison and extinction measurements. These stars have mostly received five observations each and will provide the material to extend the physical interpretation found for the narrow band magnitudes to the more usual broad band systems. For this programme Mr Willstrop made a total of 4847 four-colour observations spread over 94 nights.

Miscellaneous.—43 observations of 26 occultations were made with various telescopes. Of these 39 were disappearances at the dark limb and the remainder reappearances at the dark limb. The Observatory has continued to act as host to the very successful " Moonwatch " team consisting of over 100 volunteers under the able leadership of a well-known amateur astronomer, Mr W. P. Hirst. The team is equipped with 49 5-inch telescopes supplied by the U.S. Naval Research Laboratory and 16 2-inch telescopes with wide fields. Among the team's successes were the first observations outside the U.S.A. of the first American satellite 1958 Alpha, the discovery of the third satellite 1958 Gamma

and participation in the early observations of 1958 Epsilon which was discovered in Pretoria and of which 19 out of the first 21 observations were made in South Africa.

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Armagh Observatory

(*Director, Dr E. M. Lindsay*)

Dr Öpik was granted leave of absence for one year as Visiting Professor to the University of Maryland and left at the middle of September. Mr John Anderson was appointed as an Observer at the Boyden Observatory, this post to be held in the first instance for one year starting January 1959.

Dr Öpik continued his theoretical researches on meteors and meteorite phenomena and on planetary atmospheres, in connection with cosmogonic problems and the exploration of near space. At the University of Maryland he delivered a postgraduate course on " Introduction to Astrophysics and Geophysics ", an Astrophysical seminar on " The Surface Conditions and Atmospheres of the Moon, Venus and Mars " and a serial lecture on " Astronomy in Near Space " at the Space Research and Technology Institute of the University of Maryland.

Dr Lindsay completed the survey for emission objects in the Small Magellanic Cloud using ADH plates. These consisted of blue and red (with red filter) prism plates and blue and red with (red filter) chart plates. A total of 582 objects was found of which 53 are planetary nebulae. Blue and red magnitudes of all objects were measured on five plates using the Iris Photometer and their positions determined. From this material a New Catalogue has been prepared. A preliminary inspection of the ADH spectral plates on the Large Cloud has revealed over 1000 emission objects, of which 120 are planetary nebulae.

The primary mirror of the Schmidt camera was aluminized at Dunsink. It has been one of the worst years on record for observational work and a negligible amount of photographic material was obtained at Armagh. Brigadier Papworth followed Mars throughout opposition using the 10-inch refractor but even on the few nights available seeing conditions were never good.

Meteorological observations were carried out by Miss Sheelagh Grew.

Contributions Nos 21–24 and 26 and Leaflets Nos. 46–48 have been distributed. Contributions published or in press during the year are No. 24 " Meteor Impact on Solid Surface " and " On the Catastrophic Effects of Collisions with Celestial Bodies " by E. J. Öpik (*I.A.J.*, **5**, 1959); No. 25 " The Photoelectric Light Curve of RT Sculptoris " by G. G. Cillié and E. M. Lindsay (*M.N.*, **118**, 585, 1958) with appendix " Individual Observations of RT Sculptoris " (published by Armagh Observatory); No. 26 " Statistical Results from the Arizona Expedition for the Study of Meteors " by E. J. Öpik (published by Armagh Observatory); No. 27 " The Spike of Comet Arend-Roland 1956 h " by E. J. Öpik (*I.A.J.*, **5**, 1958); No. 28 " Perturbations of a Satellite Orbit by an Oblate Planet " by E. J. Öpik (*I.A.J.*, **5**, 1958).

Publications accepted or ready for press are " A new Catalogue of Emission Objects in the Small Magellanic Cloud "; " Planetary Nebulae in the Large Magellanic Cloud " (*Nature*); " Note on the Behaviour of a Ground Minimum Thermometer " by E. M. Lindsay.

A Monograph on " Physics of Meteor Flight in the Atmosphere " by E. J. Öpik was published by Interscience Publishers, New York and London.

Other publications include " Problems in the Physics of Meteors " (*Amer. J. Physics*, **26**, 1958), " Climate and the Changing Sun " (*Scientific American*, **198**, 1958), " Solar Variability and Terrestrial Climate " (*I.A.J.*, **5**, 1958) by E. J. Öpik.

Observations of artificial satellites were made by members of the Observatory staff. Predictions of local appearances were made by Dr Öpik and, after his departure, by Mr Grossie.

Cambridge Observatories

(*Director, Professor R. O. Redman, F.R.S.*)

Solar research.—Dr and Mrs von Klüber with Dr A. H. Jarrett (St Andrews University Observatory) were fortunate in having a clear sky for the total solar eclipse of 1958 October 12 on Atafu (Tokelau Islands). They photographed the corona in the light of the green 5303A and red 6374 lines respectively, using interference filters and a Fabry Perot interferometer. Comparison photographs were taken before and after totality using an Hg 198 isotope lamp. Well-defined interference fringes were obtained, which will serve to measure the coronal temperature out to about 1·7 radii from the centre. The expedition was financed by a Royal Society grant, through the J.P.E.C. Transportation between Fiji and Atafu was by a flying boat provided by the R.N.Z.A.F. and much other help was given by the Tokelau Islands Administration and by Dr I. L. Thomsen of the Carter Observatory, Wellington, N.Z. Thanks are also due to Kodak Ltd. for a supply of special photographic material.

Dr von Klüber has commenced preparations for the total solar eclipse of 1959 October 2 which he hopes to observe from Fuerteventura (Canary Islands).

Work on the solar magnetograph has made further progress, but has been considerably delayed by an obscure difficulty with the photoelectric guiding control on the coelostat drive. Mr Beggs has now rectified this fault and a programme of measurements on the Sun will be started shortly.

Some of the first results from photographs of the solar granulation obtained on a balloon flight (reported last year) have been communicated to the Society in a paper by Drs Blackwell, Dewhirst and Dollfus. The contrast transmission functions of the whole apparatus, including the photographic emulsion, have been measured and used to correct the surface brightness variations found on the disk. After correction the average brightness of a granule at 5300A is 1·5 times that of an intergranular region. These and other results yet to be discussed depend on calculations made with EDSAC II, by courtesy of the Director of the Cambridge University Mathematical Laboratory. The necessary programming was carried out by Dr Fellgett, who has also communicated a paper to the Society analysing earlier granulation measures. He has shown that previous conclusions concerning the scale of variations in velocity and brightness are not justified and that the

evidence for correlation between velocity and brightness changes is weaker than has been supposed.

Dr Thompson has had some success in photographing " wriggly " Fraunhofer lines, with exposure times about ½ second, using the 4th order of the large Babcock grating. Results show some changes of line profile, of a character such that equivalent widths tend to remain constant, as though the cause were changes of microturbulence. No correlation has been detected between any of the three variables: line profile, line of sight velocity and photospheric brightness. Dr Thompson has continued work on the interpretation of Fraunhofer line profiles. He finds that much of the observed absorption arises in the highest layers of the photosphere, for which there is no adequate information on the distribution of temperature with height. He concludes that the increase of line width from centre to limb is due to a turbulence increasing with height, rather than a non-isotropic turbulence; and that at least part of the line absorption arises in layers where the temperature increases with height, i.e. in layers higher than the temperature minimum between photosphere and chromosphere.

Dr Blackwell and Mr M. F. Ingham spent May to August at the Cosmic Ray Observatory of Chacaltaya, near La Paz, where at an altitude of about 17,000 ft they measured the brightness and polarization of the zodiacal light and also photographed its spectrum. About 400 calibrated photographs of the zodiacal light and the adjacent night sky were taken with a 4-lens camera working at $f/1{\cdot}8$, using various filters and polaroid screens. The extinction in both red and blue light was measured photoelectrically. The spectrum of the zodiacal light about 30° from the Sun was photographed with a large Bausch and Lomb grating and an $f/0{\cdot}8$ Schmidt spectrograph camera, giving 38A/mm in second order violet and 78A/mm in first order red. Exposures had to be continued over 7 evenings. Fraunhofer line intensities in this spectrum should give the density and kinetic temperature of the electron cloud approximately 0·5 A.U. from the Sun. Measurement of the material is making good progress. The expedition was financed by a Royal Society grant. Construction of the spectrograph camera was helped by a D.S.I.R. grant. Thanks are also due to the Director of the Chacaltaya Observatory, Dr I. Escobar V, and to Kodak Ltd. for special photographic material.

17-inch Schmidt telescope.—Mr Argue has continued his investigation of stellar photometry with in-focus images on the 17-inch Schmidt telescope, mainly using the RGU colour system. The reduction of the measures has been much speeded up by the use of EDSAC II and a further saving of time should follow when the EDSAC auxiliary magnetic tape store becomes available. Reduction time is now much shorter than measurement time.

RGU measurements in the region of Praesepe have failed to give a completely unambiguous separation of giant stars from dwarfs. This confirms a tentative conclusion reached earlier in work on SA8, but in SA8 the results are complicated by strong interstellar reddening.

The Sartorius iris photometer was returned to the Royal Greenwich Observatory early in the year, and thanks are due to the Astronomer Royal for this helpful loan. A new Becker iris photometer has since been purchased and put into use.

Dr Fellgett has made a preliminary design study for an automatic measuring engine for Schmidt photographs. Special attention has been given to the problems of detecting faint star images in the presence of photographic granularity

and of making settings for position and magnitude in such a way as to minimize the random errors caused by the granularity.

36-inch reflector.—Professor Redman and Mr Griffin have measured the 4200A CN band in the spectra of about 700 stars mostly of types G8 to K5, by the photoelectric method mentioned in last year's Report. The well-known strengthening of this band with increasing absolute luminosity is clear; the relation of weak CN to high stellar velocities is less simple than commonly supposed; " strong-line " stars have slightly stronger CN than " weak-line " stars. The G band has also been measured in about 200 of the same stars. As measured in this way its intensity is a good criterion of spectral type for giants near Ko. There is some absolute magnitude effect and the band appears to be a less valuable criterion for dwarfs. A similar programme has been started on the Mg b lines by Mr T. J. Deeming.

Radio sources.—Dr Dewhirst has spent 10 months as a guest investigator at the Mt Wilson and Palomar Observatories, examining plates taken with the 48-inch Schmidt telescope, in a search for optical identifications of discrete radio sources. Most of the radio positions were provided in advance of publication by the Mullard Radio Astronomy Observatory. Of 93 intense and reliably determined sources of small angular diameter between declination $-10°$ and $+45°$, 9 have certain optical identifications, and 12 more are identified with about 50 per cent certainty. The new and certain identifications have revealed what appears to be a hitherto unrecognized class of radio sources, consisting of close double and multiple E or So galaxies. Data were also collected on the numbers, to various limiting magnitudes, of peculiar, double, and multiple galaxies; these data will be of value in assessing the statistical significance of optical identifications with radio sources of known probable error in position.

Optics.—Dr Linfoot has made an investigation into the question of tolerances of spherical aberration combined with variation of focal setting, of a lens imaging monochromatic low-contrast fine detail on to a photographic emulsion of specified spread and graininess. A realistic quantitative assessment of the combined effects of diffraction, optical aberrations, and photographic graininess on image quality is obtained on evaluating the mean information density in the images of a low-contrast random object set. The theoretical discussion requires the use of the Fourier techniques recently introduced into this field and the practical evaluation of information densities requires the use of a fast electronic computer. Thanks are due to the Mathematical Laboratory for the use of EDSAC II and to Mr Swinnerton-Dyer who gave much help in the necessary heavy integrations.

Other investigations.—Following methods similar to those used for the analysis of solar granulation, Dr Fellgett has used EDSAC II to analyse observations of the variation of latitude. He has found that the annual term does not differ significantly from a uniform circular variation. The damping of the Eulerian motion is subject to a large uncertainty set by the period of time over which observations are available. Contrary to other earlier investigations, observational errors and smoothing of the data do not contribute appreciably to this uncertainty.

Dr Fellgett has communicated a paper to the Society on signal-to-noise relations in photography and the efficiency of various photographic emulsions. The maximum efficiency is about 0·01 and occurs at smaller photographic

densities than are commonly used. If this result is true, the potential gain of photoelectric image tubes over photography is of order 10 rather than 100.

Dr Beer has continued the measurement of Hγ in spectra of B type stars, using material obtained at the Radcliffe Observatory, Pretoria. Towards the end of the year he travelled to Victoria, B.C. to use equipment at the Dominion Astrophysical Observatory to speed up reduction of his material, and also to confer with Dr Petrie on this problem.

Professor Stratton and Dr Beer have been able to pursue work on N Her 1934 further, using recent spectrograms taken by Dr Humason with the Hale 200-inch telescope. It appears that this star is still ejecting matter continuously. There is an important difference of behaviour between 3727A, [O II], or 4077A, [S II], on the one hand and 4686A, He II, on the other.

Dr Beer has cooperated with Dr J. Needham and others in examining Chinese records relating to I-Hsing's eighth-century meridian line, making a contribution to our knowledge of the fundamental Chinese ' li '-unit and of the history of geodesy in China.

Colloquia.—The Observatory Club held nine colloquia during the year. The only speaker from outside Cambridge was Dr R. Giovanelli (Sydney).

Staff.—Mr G. P. Hills has joined the staff as a Junior Assistant and Mrs G. Richards as a temporary computer.

Mullard Radio Astronomy Observatory, Cavendish Laboratory

(*Director, Professor M. Ryle, F.R.S.*)

1. *New equipment.*—The two large radio telescopes designed respectively for the observation of radio sources at a wavelength of 1·7 m and the study of the galactic radiation at 7·9 m have been brought fully into operation.

Apparatus has also been designed and installed for the automatic encoding of the output of the radio star interferometer in a form suitable for acceptance by the electronic digital computor EDSAC.

2. *Observations of radio sources*

(*a*) *Observations at* $\lambda = 1{\cdot}9$ m.—Measurements of the positions and intensities of 471 sources with flux densities greater than $8{\cdot}10^{-26}$ w.m.$^{-2}$ (c/s)$^{-1}$ at 1·9 m have been made with the four-aerial interferometer (**1**) and are ready for publication (**2**). Information on the angular diameters of 72 of these has also been determined.

The accurate positions of 17 of the bright sources have also been found (**3**) by a different technique in order to check the methods used to compile the catalogue. There is good agreement between the independent measures.

(*b*) *Search for optical identifications.*—This work has been left to Dr D. W. Dewhirst and his results are summarized in the report of the Cambridge Observatories.

(*c*) *Observations at* $\lambda = 1{\cdot}7$ m.—Tests of the large interferometric radio telescope (**4**) were completed in early summer and regular observations have been in progress since August 1958. Three separate programmes are now in hand :—

(i) A survey of sources down to the limit of observation, using the principle of " aperture synthesis " to produce an interferometric reception pattern with a lobe spacing of 8′ contained within an envelope $25' \times 35'$.

Two series of observations have been completed, covering the range of declinations 48°–54° N, and one of these has been reduced using the EDSAC computor of the University Mathematical Laboratory.

(ii) An investigation of the angular extent of the brighter radio sources (down to flux densities of about $5 \cdot 10^{-26}$ w.m.$^{-2}$ (c/s)$^{-1}$) using parts of the instrument combined in different ways. This survey allows the measurement of the angular diameters of sources throughout the whole range of diameter 1′ to 60′, with almost uniform sensitivity.

(iii) A series of positional measurements have been made of the 60 most intense unidentified sources, to extend the series completed recently at $\lambda = 1 \cdot 9$ m. By measuring what is in effect the change of phase of the wave with the North–South position of the movable aerial, the elevation and hence declination of a source may be found with an accuracy much greater than that of any previous measurements.

(*d*) *Observations at* $\lambda = 74$ cm.—The four-aerial interferometer (1) used previously at $\lambda = 3 \cdot 7$ m and $1 \cdot 9$ m has now been modified for use at $\lambda = 74$ cm, in order to obtain further information on the spectra and angular diameters of as many sources as possible.

(*e*) *Evidence on the nature of radio stars.*—An analysis has been made of all the available radio evidence which bears on the problem of the nature of the radio stars (5). It has been shown that by relating their "number-magnitude" relationship, the observed isotropy of the sources of small angular size, and the maximum integrated emission which is compatible with observations of the background radiation, it is possible to draw important conclusions on the permissible values of the average absolute luminosity and space density of radio stars. Unless it is assumed that the dispersion in luminosity is small, even the present observations make it difficult to suppose that most of the sources are within the galaxy. If they are outside the galaxy their luminosities must be very much greater than those of nearby galaxies and must approach those of the most powerful colliding galaxies.

The recent observations by Dewhirst of additional identifications with multiple elliptical galaxies have given values for the radio luminosities of these sources which agree with the conclusions.

The further development of this analysis by more detailed observations is now of great importance.

3. *Observations of the galactic radiation.*

(*a*) *Survey at* $\lambda = 7 \cdot 9$ cm.—The large instrument employing the principle of "aperture synthesis", consists of an array running East–West, with a length of 3300 ft, used in conjunction with a small aerial which may be moved along a North–South line running through the centre of the fixed one (4). A preliminary survey of part of the sky from $\alpha = 16^h$–18^h and $\delta = +10°$ to $+50°$ has been made to test the instrument, and to obtain experience with the problems of computation. In this survey spacings between the aerials of up to 13λ were used, so that the resolution is $1° \times 4°$.

A survey with spacings up to 30λ is now in progress.

(*b*) *Observations at* $\lambda = 1 \cdot 9$ m.—A survey of the galactic radiation between $\delta = -28°$ and $+60°$ has been carried out, using one quarter of the four-aerial interferometer, and the reduction of the data is nearing completion.

(*c*) *Observations at* $\lambda = 1{\cdot}7$ m.—The large aerial of the new radio star interferometer is being used for measurements of the galactic radiation. The beam-width between half-power points is 21′ in α and 5° in δ.

(*d*) *The density of the galactic halo.*—A comparison (**6**) of observations by other workers of the galactic radiation at 100 Mc/s and at 2·1 Mc/s provides a very sensitive test for the presence of ionized hydrogen in the galactic halo. Assuming the temperature to be 10^4 °K an upper limit of $2{\cdot}10^{-2}$ cm^{-3} has been set for the mean density of ionized hydrogen.

(*e*) *Investigation of the "Supergalaxy".*—It has previously been suggested that a particular region of enhanced emission in the background radiation is associated with the concentration of bright galaxies termed the "Supergalaxy". A number of arguments (**7**) have been advanced against this hypothesis and it has been concluded that the feature is galactic in origin.

4. *Solar observations*

(*a*) *The outer corona.*—The occultation of the Crab nebula was again observed in 1958 June. In one series of measurements, at a wavelength of 7·9 m, interferometers were used to determine the scattering in three different directions. Marked anisotropy of scattering was detected which suggests that the solar magnetic field is radially directed to distances of at least 30 radii. In addition, the 3,300 ft array was employed to give a 1° fan beam to investigate the large scattering and the variation of total intensity of the nebula at closest approach. Some of these results together with those of previous years have been published (**8**) and a detailed account of the 1958 observations will appear shortly (**9**).

(*b*) *Active regions.*—The measurements of angular size and position of short duration radio bursts have been continued and extended.

(*c*) *Routine observations.*—The I.G.Y. programme in which the solar intensity was continuously recorded on $\lambda = 3{\cdot}7$ m and 1·7 m has terminated. Measurements will be continued, but they will not necessarily be so complete as hitherto.

5. *The relation between radio emission and cosmic ray electrons*

A consideration (**10**) of the mechanisms of production and energy loss of cosmic ray electrons leads to an energy spectrum for such electrons compatible with the observed frequency spectra of radio sources, on the assumption that the radiation is due to the synchrotron process.

6. *Earth satellites*

A study of the fluctuations of signals received from the first Russian earth satellite at $\lambda = 15$ m and 7·5 m has enabled them to be definitely attributed to physical rotation of the satellite and Faraday rotation of the plane of polarization of the wave during passage through the ionosphere (**11**). The rate of rotation and orientation of the satellite have been derived.

Other accounts of the satellite observations have been published (**12, 13**).

A system of world-wide navigation based on the reception of radio signals from earth satellites has been proposed (**14**).

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Glasgow University Observatory

(*Director, Professor W. M. Smart*)

The research work of the department during 1958 was somewhat curtailed owing to the vacancy in one of the posts for part of the year. Dr A. E. Roy joined the department as Lecturer on 1958 April 1.

Dr M. W. Ovenden and Dr Roy have renewed their investigation of the structure of the solar system. They have also been examining the validity of certain applications of the Jacobi integral in the restricted three-body problem.

Dr Ovenden, with the advice of Dr A. Wasserstein of the Department of Greek, has been considering the information which the works of Aratus and Hipparchus can give about the origin of the constellation figures.

Dr Roy has been developing the principles of a new statistical method of storing information.

A "Moonwatch" team is being established at the Observatory for the observation of artificial satellites.

University of London Observatory

(*Director, Professor C. W. Allen*)

Theoretical work and analysis.—Dr P. A. Sweet has investigated the general conditions in which high electric current densities can occur in astrophysics. The process can be termed the hyperbolic pinch effect. It can occur elsewhere than at neutral points in the magnetic field. Dr R. H. Garstang has extended his methods of computing electric quadrupole line strengths to transitions of the forms $d^{n-1}s-d^{n-1}s$ and $d^{n-1}s-d^{n-2}s^2$, and carried out detailed calculations for $n=9$ and $n=7$. Calculations on [Ni II] and [Fe IV] were completed during the year. The Fe IV calculations included predictions of the energy levels of the lowest configuration and of the wavelengths of forbidden lines. Calculations on [Fe II] were commenced; the fitting of observed energies to theory was completed and good progress made towards the calculation of magnetic dipole line strengths. The Director has analysed available line intensities for elements of the iron group and derived empirical rules for the absolute oscillator strengths of various types of transition. Mr T. Kiang has continued his statistical studies of asteroids. Mr J. S. Griffith continued integrations of the structure equations for rapidly rotating stars and investigations into circulation currents therein.

Spectroscopy.—Most of the year was spent in technical developments for recording absolute spectrum line intensities by both photoelectric and photographic methods. O and H lines which had been measured photographically

have been remeasured more accurately by Mr E. W. Foster using electronic recording. Mr J. B. Tatum has succeeded in exciting the spectrum of Fe in a water vortex arc. Dr Garstang has completed a study of the intensities of lines in the red spectral region of 9 Pegasi (G5 Ib).

Artificial satellites.—Some visual and photographic observations of the position and time of passage of various artificial satellites have been made during the year, mainly by Mr J. B. Tatum. Results have been sent to the prediction centre. Five cameras for satellite observation have been constructed in the workshop and distributed to various observers.

Use of telescopes.—The Radcliffe 24-inch refractor was used on 14 nights for photography of Selected Areas (for proper motions), on 3 nights for the investigation of the magnitude equation, on 4 nights for photoelectric observations of nova RS Oph, and on 2 nights for photography of the minor planets Iris and Nemausa.

Proper motions.—Three proper motion plates were measured and reduced by Mr T. Kiang and Miss G. C. Goldwin.

Publications.—The following papers have been published during the year 1958:

C. W. Allen, " Absolute oscillator strength measurements in Mg, Ca, and other atoms ", *M.N.*, **117**, 622, 1957.

W. R. Piggott and C. W. Allen, " Observational aspects of solar corpuscular radiation ", *9th Rept. on Sol. Terr. Relations*, p. 77, 1957.

C. W. Allen, " Solar Radiation ", *Quart. J. R. Met. Soc.*, **84**, 307, 1958.

P. A. Sweet, " The topology of force-free magnetic fields ", *The Observatory*, **78**, 30, 1958.

P. A. Sweet, " The production of high energy particles in solar flares ", *Nuovo Cimento*, Supp. to **8**, 188, 1958.

P. A. Sweet, " The neutral point theory of solar flares ", *I.A.U. Symp. No.* 6, " Electromag. Phen. in Cosmic Phys.", 123, 1958.

P. A. Sweet, " Magneto-hydrostatic equilibrium in an external magnetic field ", *I.A.U. Symp. No.* 6, 499, 1958.

R. H. Garstang, " Further computations of quadrupole line strengths ", *Proc. Camb. Phil. Soc.*, **54**, 383, 1958.

R. H. Garstang, " Transition probabilities for forbidden lines of Ni II and Ni III ", *M.N.*, **118**, 234, 1958.

R. H. Garstang, " Recent experimental and theoretical investigations on atomic properties of interest for emission-line stars " 1957 *Liège Symposium No.* 8—*Mem. Soc. Roy. Sci. Liège*, **20**, 497, 1957.

R. H. Garstang, " The surface temperature of the Moon ", *J.B.A.A.*, **68**, 155, 1958.

Staff, students and visitors.—No staff changes occurred. Dr P. A. Sweet returned in July from his year in Berkeley. Miss G. C. Goldwin worked with us for six weeks during her student vacation. The Department has had two research students during the year and twelve undergraduate students have taken regular lecture courses since October. There were 381 afternoon and evening visitors.

Royal Radar Establishment, Ministry of Supply, Malvern

The 45 ft radio telescope has given excellent performance, and the radar observations at 10 cm wavelength of the first Russian earth satellites came up to theoretical expectations. This work was followed by radar observations of the Moon, and preliminary results were described at the I.A.U.–U.R.S.I. Symposium on Radio Astronomy, 1958. Because of the short pulse length, 5 microseconds,

it was possible to make distance measurements accurate to about 1 km, and to examine the characteristics of the Moon echo in detail and hence obtain information about the type of surface mainly contributing to the reflected wave.

The attempt to detect the 327 Mc/s deuterium line in the galaxy was continued with the Jodrell Bank radio telescope which Professor Lovell kindly made available for this experiment. Although the results were again negative, it has been possible to reduce further the observational upper limit to the abundance of deuterium. This limit is now close to the terrestrial abundance, and details were described at the I.A.U.–U.R.S.I. Symposium, 1958. A further attempt will be made when the equipment has been modified to give improved performance.

The most important development in radio astronomy at the Royal Radar Establishment is the construction of a radio telescope interferometer to be completed in 1960. The equipment will consist of two steerable radio telescopes of 25 m diameter mounted on railway tracks for use as an interferometer with variable spacing. Each telescope is similar to the 25 m radio telescope in Holland; the principal differences are in the new mobile mounts and in the central areas of the reflectors, approximately 75 per cent of the diameters, which are to have finer mesh to enable the aerials to be used at 10 cm wavelength. It will thus be possible to use the aerials either as separate radio telescopes or together as an interferometer at all wavelengths down to 10 cm, and the equipment will provide a particularly versatile and accurate radio astronomy instrument.

Jodrell Bank Experimental Station, University of Manchester

(*Director, Professor A. C. B. Lovell, F.R.S.*)

The radio telescope.—This report covers the first complete year of use of the radio telescope. Until the late summer the full use of the instrument for research purposes was limited by completion of miscellaneous engineering work, but by the end of the year the telescope was in systematic use and its rate of use for the research programmes was twelve hours per day. The telescope has proved to be entirely satisfactory. Its performance is near to the theoretical value up to a radio frequency of 1000 Mc/s per second; at higher frequencies its performance begins to deteriorate but at 1420 Mc/s the power gain is still appropriate to that of a 150 ft reflector, and the beam width to that of a 200 ft reflector.

Galactic and extragalactic radio emissions.—(i) 160 *Mc/s survey of galaxies.*—A survey of 28 bright galaxies has been carried out with the 250 ft paraboloid at a frequency of 160 Mc/s. It has been shown that the observed ratio of radio to light flux is a function of the apparent angular size of the radio source, the inclination of the visible nebula and the galactic latitude; suitable corrections for these factors have been derived. The results suggest that the ratio does not differ greatly for Sb and Sc galaxies, but that irregular galaxies may perhaps show a significantly higher ratio of radio to light. These tentative conclusions must be verified by more extensive observations with a narrower beam, since it cannot be excluded that the faintest sources in the 160 Mc/s survey are affected by confusion.

In the course of this survey the two bright spirals M31 and M33 were observed and the results are to be published (1). Integrated radio magnitudes for both these galaxies have been measured. The isophotes of M31 show that the corona is elliptical in outline and has angular dimensions of about 11°×7°. It

was found that the radio source associated with M33 is also much larger than the visible nebula.

(ii) 408 *Mc/s survey of M31 and the Cygnus region.*—A survey of the Andromeda nebula at 408 Mc/s has been carried out using the 250 ft paraboloid (**2**). At this frequency the beam width is 40 × 56 minutes of arc. The isophotes confirm that radio emission is detected from a broad corona of the galaxy, and reveals a complex structure within the corona. It is also shown that the emission from the satellite nebula NGC 205 is less than from a normal spiral galaxy of the same photographic magnitude. A survey has been made of the Cygnus X region. Comparison of the isophotes with those obtained at 21 cm confirms the presence of a large number of sources, and lends support to the hypothesis that the emission is largely from an H II region.

(iii) *A survey of the Coma cluster.*—The Coma cluster of galaxies has been surveyed at 158, 240 and 408 Mc/s using the 250 ft paraboloid. It has also been surveyed with an interferometer at 158 Mc/s using a number of baselines in different position angles. The results are being examined together, and it is hoped that they will yield some reliable information on the radio emission from this cluster. It is difficult to interpret any one survey, because there are a number of discrete sources of small angular diameter in this region. The 408 Mc/s survey is in course of publication (**3**).

(iv) *Lunar occultation experiment.*—Some preliminary attempts have been made to observe lunar occultations of weak radio sources at 158 Mc/s. The aerial beam, which at this frequency is about 2 degrees between points of half intensity, was directed so that the Moon was placed centrally in the beam and the telescope programmed so as to track the Moon across the sky. Two possible occultations were observed in these preliminary runs. The experiment is to be repeated in the autumn with more sensitive equipment and it is considered that accurate positions and diameters should be obtained for a considerable number of sources.

(v) *Optical interferometer.*—The series of papers on the interferometry of the intensity fluctuations in light has been completed by papers dealing with the application of the technique to astronomy (**4**) and a test on Sirius (**5**). A design study of a practical stellar interferometer is at present in progress.

Radio star scintillations.—The continuous monitoring of Cassiopeia (23N5A) at 79 Mc/s and the three-station ionospheric drift experiment, have been continued as a contribution to the I.G.Y. A statistical analysis of the accumulated results from both experiments is now in progress. An investigation has been made into the absorption of 36 Mc/s and 100 Mc/s extra terrestrial radio waves at low angles of elevation (**6**). During this experiment, some evidence was obtained which indicated that scintillations are caused, under some conditions, by irregularities at E-region heights.

A few observations of radio frequency noise apparently of auroral origin prompted a long term investigation into this problem. Five separate aerials were positioned to monitor continuously various sectors of the sky. During a period of intense solar activity, examples were obtained of radio noise emission from some sectors of the sky concurrent with absorption in other sectors (**7, 8**).

Using records obtained with various receiving equipments a thorough examination has been made of the variation of scintillation characteristics in the frequency range 26 Mc/s to 408 Mc/s (**9**).

Diameter of the radio sources.—Observations with the two aerial interferometer at 2800 Mc/s have been concluded by measurements on the major axis of the Cygnus (19N4A) source using approximately east–west baselines of lengths up to 1750 wavelengths. These results (10) suggest that the separation between the two centres of emission is about 20 per cent larger than at metre wavelengths if the direction of the major axis is assumed to be independent of frequency. An account of the measurements of the distribution of intensity of the Cassiopeia and Cygnus sources has now been published (11). The measurements were made on a frequency of 127 Mc/s using a high resolution phase sensitive interferometer.

The construction has continued of an improved interferometer at 160 Mc/s using long baselines and radio links. Development work on a microwave radio link was started during the year. It seems likely that this system will combine a microwave link with a C.W. transmission near the signal frequency to maintain phase coherence. An outstation has been established 4 km west of Jodrell Bank, and will be available for the forthcoming tests of the radio link.

The outstations using cable links have been used, with the steerable telescope, for three observational programmes during the year. The maximum of radio emission near 12^h R.A. was observed with interferometer spacings of 70λ and 320λ and was shown to contain many sources with diameters smaller than five minutes of arc. The same aerial spacings were used for observations of the radio source in the position of the Coma cluster, and these observations were extended using a small mobile paraboloid (25 ft diameter) as the remote aerial.

The reconstruction of the transit telescope (218 ft diameter) was completed in July 1958. It has since been used as the remote aerial for the interferometer in observations of the Andromeda and other extragalactic nebulae and to provide confusion limited records for a statistical investigation.

The 21 cm spectral line of neutral hydrogen.—The 250 ft steerable radio telescope has been extensively tested at a wavelength of 21 cm and it was found that the main beam had a width to half-power points of $15' \times 20'$. The first experiments which involved measurements on the absorption spectra of the intense radio sources were designed to take advantage of the large effective collecting area of the telescope.

An attempt was made to determine the strength of the galactic magnetic field by observing Zeeman splitting in the narrow 21 cm absorption line of Cassiopeia A. No detectable effect was observed and an upper limit to the line-of-sight magnetic field in the local spiral arm was estimated at 5×10^{-5} gauss.

The red shifted absorption spectrum of Cygnus A at 1340 Mc/s was also investigated. An upper limit of the optical depth of the absorption at this frequency was 0·01 compared with a value of 0·06 claimed by Lilley and McClain. The experiment is being continued in an attempt to detect a smaller effect and to determine a value for the density of intergalactic neutral hydrogen.

The entire sky visible from Jodrell Bank has been mapped in the 21 cm emission from neutral hydrogen using the 30 ft paraboloid. This survey on a grid $5^\circ \times 5^\circ$ gives a picture of the distribution of neutral hydrogen within a distance of several hundred parsecs of the Sun (12). An effort was directed to an endeavour to eradicate variations in the background level of the spectrometer when the frequency scans and the spacing of the reference channel were of sufficient magnitude for use in reliable extragalactic work on the 250 ft radio telescope. The difficulties were finally attributed to a redistribution of the noise spectrum

generated in the low noise intermediate frequency amplifying stage following the crystal mixer. No satisfactory solution to this problem was found with the existing general technique and an auxiliary small equipment employing switched intermediate frequency channels and variable first local oscillator was developed. This apparatus was shown to avoid the difficulties encountered with the original technique though the new system lacked the long term drift stability and frequency stability of the old method.

Aurorae.—Radio echo observations of the Aurora Borealis were continued throughout 1958 using low power equipments on a wavelength of 4 m. There was a marked decline in activity compared with 1957. Echoes were obtained during 20 days and 81 hourly periods during 1958 whereas the values for 1957 were 29 days and 107 hourly periods. This indicates that the peak auroral activity of the present sunspot cycle occurred during 1957 and that the incidence of aurorae will decrease progressively until the next sunspot minimum. Aurorae of exceptionally high intensity occurred on July 8/9 and September 4/5, the latter giving rise to 15 hours of almost continuous activity.

It has been found that auroral echoes are detected at Jodrell Bank only from a restricted region in the sky at a height of about 110 km such that the line-of-sight is perpendicular to the local magnetic field lines, i.e. specular reflection. The vertical thickness of the echo regions is less than 10 km and there is some evidence which suggests that the height of the echo regions decreases with increasing magnetic activity. The detection of echoes is dominated by the specular condition and no echoes have have been obtained from regions as little as 3° from specular.

It has been confirmed that the occurrence of moving echo regions is closely associated with large magnetic disturbances near these regions. It therefore seems probable that the ionized echo regions constitute the current systems which give rise to magnetic disturbances. The detection of echoes at Jodrell Bank is usually accompanied by a penetration of visual aurorae south of geomagnetic latitude 62°N and by the observation of rayed auroral forms.

A preliminary comparison between radio echo observations made at Jodrell Bank and Halley Bay, Antarctica, has been carried out (**13**). It has been shown that radio echo activity at Halley Bay is closely associated with the planetary K index (K_p) and that activity at Jodrell Bank corresponds to the peaks in activity at Halley Bay.

Meteor orbits.—The three station orbits equipment was operated during the Boötid, Giacobinid and Ursid showers. With the equipment sensitive to meteors of 7–8 magnitude, no Boötid activity was observed on January 16–17. The analysis is proceeding of the 4–5 magnitude sporadic meteor survey.

Meteor photography.—The Main Model Meniscus Schmidt camera at Abersoch in North Wales has been in operation throughout 1958. Observations of sporadic and shower meteors have been made whenever sky and moon conditions have permitted. 64 meteors have now been photographed with this instrument and nine have had radio echoes associated with them. The analysis of these observations is in progress.

The bright Geminid meteor of absolute visual magnitude $-2\frac{1}{2}$ which was referred to in the report for 1957 has been analysed. It has enabled the attachment coefficient of electrons to neutral molecules to be determined (**14**). This is found to be an order of magnitude greater than the theoretical estimate which has

been the only value available until now. An attachment coefficient of this order has been shown to explain quantitatively the departure of radio echo observations of meteors from the simple diffusion theory (**15**).

E-Region Winds.—Radio echo measurements of E-region winds by the observations of the drift of ionized meteor trails (**16**) have continued throughout 1958 as part of the I.G.Y. programme. Wind determinations were made during Regular World Days as well as those Special World Intervals that showed signs of magnetic or auroral activity. The prevailing diurnal (24 hour) and semi-diurnal regular winds have been evaluated and their structures and seasonal variations have been found to be in agreement with previous year's results (**17**).

Further studies have been made of the turbulent winds. There appears to be a hierarchy of turbulent eddy sizes ranging from the largest anisotropic eddies of vertical and horizontal dimensions of 7 and 150 km respectively, r.m.s. velocity 25 m sec^{-1} and time constant 6×10^3 sec to the smallest eddies of 50 m dimension, 30 sec time constant and 1·5 m sec^{-1} r.m.s. velocity (**18, 19**).

Upper atmosphere densities and temperatures.—The investigation of atmospheric densities and temperatures at altitudes of 90 to 100 km, using radio echoes from meteor trails has continued. Densities are determined by observation of the rate of diffusion of ionized meteor trails while the meteor heights are measured using a radio direction finding method. The variation of density with height enables the atmospheric scale height (H) to be determined, H being directly related to the temperature. The mean scale height throughout the day is found to be 6·4 km, which for an average molecular weight of air of 29 at a height of 95 km gives a temperature of 210°K. The diurnal variation in temperature is found to be less than ± 10 per cent of this value. A peak to peak diurnal variation in atmospheric density of 20 per cent has been measured. This variation can be resolved into two periodic components with periods of 24 hours and 12 hours of approximately equal amplitudes (**20**). The 24-hour component corresponds to a density maximum at about $15^h\ 00^m$ U.T., while the semi-diurnal component has density maxima of $03^h\ 00^m$ and $15^h\ 00^m$ U.T.

Lunar echoes.—During 1958 the moon echo equipment was transferred in its entirety to one of the towers of the 250 ft paraboloid, where suitable enclosures and platforms were made to house it. Because the operating frequency of the equipment (120 Mc/s) lies in the aircraft navigational frequency band and the aerial is so high above the ground, complaints of interference were received, and it was necessary to rebuild the equipment on a frequency of 100 Mc/s.

The equipment has been operated at intervals throughout the year in experiments on the radar observation of artificial earth satellites. These are discussed elsewhere. Only for one period during June was it possible to make further studies of lunar echoes. In a series of experiments it was shown (*a*) that it is possible to eliminate Faraday (ionospheric) rotation fading by using circular polarized waves and (*b*) that the rate of the rapid libration fading is closely correlated with the rate of the Moon's libration spin which has a large diurnal variation. The power spectrum of the echoes computed from these observations, confirmed the results of those made earlier at 120 Mc/s which indicated that 50 per cent of the returned power arises as a result of reflection from a region at the centre of the disk having a radius only 1/10th that of the Moon. These observations were reported at the 1958 Radio Astronomy Conference in Paris. It is proposed to make further ionospheric studies by measurement of Faraday

rotation using the switched frequency technique employed previously, but also using the receiver as a polarimeter by switching between mutually perpendicular primary feeds. These observations will be limited only by the amount of time that the Moon is above the horizon and not to just one hour as with the previous aerial system. It is hoped that some insight into the distribution of electrons in the upper ionosphere may be gained by comparing these observations with those of the Faraday fading of artificial earth satellite signals observed at 108 Mc/s.

Radar observations of artificial earth satellites.—Observations of artificial satellites have been made using the 250 ft paraboloid simultaneously at two frequencies of 36 Mc/s and 100 Mc/s. The primary feed systems for the two equipments are mounted at right angles to minimize mutual interference. The 36 Mc/s equipment is one of the station meteor equipments connected to the telescope via long transmission lines, whilst the 100 Mc/s equipment is the moon-echo equipment operating at short pulse lengths. The parameters of the two systems are given in the table below:

	36 Mc/s	100 Mc/s
Transmitter power (at the aerial)	10 Kw	6 Kw
Transmitter P.R.F.	18 pps.	37 pps.
Transmitter pulse length	200 microseconds	1 microsecond
Receiver bandwidth	5 Kc/s	1 Kc/s
Receiver noise factor	limited by sky noise	3 dB
Aerial beamwidth between half power points	8°	$2\frac{1}{2}$°

Observations have been made of the carrier rockets of Sputnik II (1957 β I) and Sputnik III (1958 δ I) (**21, 22, 23**).

The motion of the satellite is such that it cannot be followed by the 250 ft paraboloid since the demanded angular speeds are too high. In consequence only observations of the satellite moving through the aerial beam have been made. This limits the observing time at 36 Mc/s (8° beam) to about 20 seconds, and at 100 Mc/s ($2\frac{1}{2}$° beam) to about 7 seconds. Nevertheless this has been sufficient to allow a study of the fading characteristics at the two frequencies, which has shown that the re-radiation pattern of the rockets is essentially that which would be expected from a long (about 80 ft) thin object. Also it appears that the rockets tumble ' end over end ' with periods which are in good agreement with those derived by visual observations.

Reception of radio signals from artificial earth satellites: (i) Equipment has been assembled to measure the rate of change of the Doppler shift in frequency of signals from satellites during transits; this gives the time of closest approach. This work is carried out in cooperation with the United States Air Force Space-track organization to enable the orbital elements satellites to be determined.

(ii) It is planned to study the fading in signals at 108 Mc/s from the first Vanguard satellite, 1958 β II. As this satellite is substantially outside the ionosphere at perigee, the Faraday fading in its signals should give unambiguous information about the total electron content of the ionosphere. Horizontally and vertically polarized components will be received independently, and suitable aerial arrays have been built. A two-channel receiver is being constructed. Initial tests with the aerials and a communications receiver show that the signal strength is satisfactory.

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University Observatory, Oxford

(*Director, Professor H. H. Plaskett, F.R.S.*)

Observations.—In spite of the poorness of the 1958 season, observations for five investigations were completed. With the 35·2 m telescope and the Bausch and Lomb grating in the first order, A. J. Meadows secured 100 spectra to find the rotational velocity and the limb effect of the chromospheric He D_3-line. A. B. Hart used the same equipment to get spectra in the second order of chromospheric H and K. With the 19·8 m tower and the Babcock grating, small-image spectra were secured by the Director for a survey of local velocity-fields. Subsequently, with the same tower, a large solar image and the Bausch and Lomb grating, S. Nichols obtained interferometric spectra of K in a continuation of his 1957 programme and M. G. Adam chromospheric spectra of Hα.

Limb-effect.—Dr. Adam has completed the measurement of 261 limb spectra, obtained in the equatorial region at 6300A in 1957. There are sufficient spectra to minimize the effect of local velocity-fields, but at the extreme limb seeing and small-angle scattering distort the true change of wavelength with position on the disk. From velocities measured in the scattered light outside the limb Dr Adam has derived an obliteration function and has solved the integral equation to find the true limb-effect.

Solar rotation.—The measurement and reduction of small-image spectra of the Sun secured in 1953 for a new determination of solar rotation were completed in the year under review. They reveal a north–south asymmetry in the equatorial acceleration and the presence of meridional currents. A paper summarizing the results and suggesting a new interpretation of the equatorial acceleration has been communicated to the Society.

Interferometric determination of wavelengths.—The interpretation of the results of the two previous investigations depends upon a knowledge of absolute

solar wavelengths to a milliangstrom. The interferometric determination of solar wavelengths by M. G. Adam's circular-channel method is thus becoming a vital necessity in problems other than that of the solar red-shift. A substantial addition to such absolute wavelengths has been made by Dr Nichols and Mr Clube (**4**); the resulting red-shifts show the same statistical dependence on line strength as previously though with a noticeably increased dispersion.

Pressure broadening and pressure shifts.—Dr Hindmarsh (**1, 2, 3**) has completed the first stage of his laboratory investigations and finds that the resonance line 4227A of Ca I does not show the shift predicted by the Lindholm-Foley theory. An extension to the inter-system line 6573A of the same spectrum is now in progress. This work is of importance not only in the interpretation of the solar red-shift, but even more in the understanding of inter-atomic forces. The Royal Society has made a grant to Dr Hindmarsh to enable him to extend his investigations to lines originating on excited levels.

Semi-automatic measurement.—As a result of a grant from D.S.I.R. the Observatory has been fortunate in securing the services of Dr A. D. Petford for an investigation of methods of measurement of line displacements in solar spectra. He has already developed one promising method of semi-automatic measurement, and the apparatus for its application is now in course of construction.

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University Observatory, St. Andrews

(*Director, Professor E. Finlay-Freundlich*)

Scientific research

(*a*) *Schmidt-Cassegrain telescope.*—The lower heavy part of the mounting for the 37-inch Schmidt Cassegrain, manufactured by Messrs. Harland Engineering Co., Alloa, has been installed.

The dome (23 ft inside diameter) was put into position by Messrs. Henry Hope & Sons Ltd., Birmingham. The units to carry the telescope, comprising the compensating fork and the central tube, have been designed and should be soon under construction. This applies also to the mechanism of the floating tube carrying the Schmidt plate.

The Schmidt plate itself is being figured under optical tests; the floating system for its defining tube is nearly completed.

The observer's platform attached to the dome is under construction; the servo control and setting mechanism is designed.

(*b*) *Auroral station* (*Dr Jarrett*).—The all-sky camera for recording aurorae has been in operation every night and the films forwarded to the appropriate I.G.Y. centres.

The *f*/0·7 spectrograph has yielded some twenty auroral spectra during the winter months.

A multiplier scanning spectrograph is under construction for auroral and night sky investigations.

(*c*) Observations with the 20 inch Schmidt Cassegrain by Mr T. Slebarski and Dr J. Cisar continued.

(*d*) Mr E. Forbes collected extensive material of solar spectra with the tower telescope in Arcetri (Florence). For the reduction of the observations of the solar red shift, Professor ten Bruggencate offered the use of the comparator in Göttingen, which has been used already during the past winter. The research is going on.

(*e*) Professor E. F. Freundlich's text book on " Celestial Mechanics " has been published.

(*f*) Miss B. Middlehurst has worked on densitometer tracings of spectra of spectrum variable HD 124224 (spectral type AOp).

Norman Lockyer Observatory of the University of Exeter

(*Superintendent, Mr D. R. Barber*)

Staff.—The appointment of Mr S. F. H. J. Archer, a graduate of the University of Cape Town, as Research Fellow from 1958 August 1 has made the staffing problem less acute, with a consequent improvement in the rate of progress of the current research programmes.

Night work.—All three telescopes have been in use during some period of the year. Spectra of γ Cassiopeiae were secured with the 9-inch Kensington prismatic camera by Mr Barber on 4 nights; and Mr Barber and Mr Archer have used the 12-inch McClean prismatic camera on 16 nights for colour temperature plates. The Mond Astrograph was used by Mr Barber on 4 nights to photograph the nebulae near γ Cassiopeiae in blue and red light, and by Mr Archer on 26 nights for photoelectric observations (see below).

Colour temperature.—Work on the current programme of relative gradients has been accelerated now that a second observer is available. Thirty-three spectrograms of Greenwich primary, and N.L.O. secondary standard stars were secured during the year, and microphotometer records of earlier plates have been made. A further series of visual, and far-red spectrophotometric gradients of γ Cassiopeiae has been reduced from tracings of 59 spectra photographed between 1951 April and 1958 December; the results are being prepared for publication.

Photoelectric observations of variable stars.—In order to make use of moonlit nights unsuitable for accurate photographic work, Mr Archer has commenced a limited programme of variable-star observing with his photoelectric photometer (1) used at the focus of either the Mond 120 cm Zeiss triplet, or the McClean 10-inch Grubb objective. A working list of selected eclipsing, short-period, and irregular variables (including γ Cassiopeiae) has been prepared.

Twilight airglow.—Routine photographic photometry of the twilight sky at 5893 A was continued during 1958 as weather conditions permitted. Satisfactory observations were obtained on 10 evenings. For the reduction of the twilight photograms a new visual densitometer has been purchased from Kodak Ltd., and is now in use.

Library.—Grateful acknowledgment is made to the Society for an allocation of £30 from the Plummer Bequest to assist in meeting recurrent binding expenses and subscriptions to journals.

Visitors.—During 1958 ' Open Days ' were held on June 23 for members of the University and Observatory Corporation; and on June 26 for the general public, when 385 persons attended. The total number of visitors for the year was 595.

Reference

(1) *J.B.A.A.*, **68**, 264, 1958.

Dunsink Observatory
(Director, Professor M. A. Ellison)

Solar work.—Observations with the spectrohelioscope were continued at fixed hours (16^h00^m–18^h00^m in summer, 12^h00^m–14^h00^m in winter) as part of the flare patrol organized for the I.G.Y. The recorder, which gives the integrated level of radio atmospherics on a frequency of 27 Kc/s, has been in continuous operation. The records of sudden enhancements of atmospherics (S.E.A.'s) and of flares have been despatched monthly to the three World Data Centres.

Some preliminary experiments were carried out by Dr Smyth with photoelectric equipment attached to the concave grating spectrograph: the aim of this work is to detect Doppler displaced H- and K-line absorption due to approaching streams of particles emitted from solar flares.

As from 1958 November 1 the Observatory assumed responsibility for the analysis of the Lyot Hα Heliograph films taken daily at the Royal Observatory, Cape of Good Hope. The Heliograph was built in the years 1956–57 by the firm S.E.C.A.S.I. of Bordeaux, the cost having been borne by a grant of £17,000 from the British National Committee for the I.G.Y. The Heliograph was erected and brought into use by Professor Ellison at the Cape in 1958 February and March. The instrument (see description in *Nature*, **182**, 624, 1958) is fully automatic, being designed in accordance with the most advanced principles of electronic automation, and it photographs the Sun's hydrogen atmosphere at 1-minute intervals for 7 hours each day. The band-pass of the Lyot filter is 0·7 A.

During the first 9 months of operation, which included a phenomenally clear winter at the Cape, films were obtained on 230 days out of a possible 295, and 694 flares were recorded (see also report of Royal Observatory, Edinburgh, p. 356). By arrangement with the Royal Society and the Admiralty, the Heliograph will be operated jointly by the Cape and Dunsink during the next five-year period.

Stellar work.—The comparison stars, used in the 1957 programme of photometry of the nucleus of Comet Arend-Roland, have been re-measured and compared with the N.P.S. The photometric reductions are complete, and the possible relationship to various forms of solar activity is being investigated.

Miss McKenna and Dr Smyth obtained photoelectric measurements with the 28-inch reflector of the recurrent nova RS Ophiuchi about the time of light maximum in July.

The photoelectric observations of 12 (DD) Lacertae, obtained by Dr Smyth with the 28-inch reflector during the 1956 international co-operative programme, were published in *The Observatory*, **78**, 82, 1958.

Mr N. J. Woolf and Mr W. L. W. Sargent, of the Manchester University Department of Astronomy, visited Dunsink in August to carry out experiments with the solar tower telescope and concave grating spectrograph in connection with high-resolution stellar photoelectric spectrophotometry.

Photographs of artificial satellites 1957β, 1958 δ_1, and 1958 δ_2, were taken with miniature cameras, timing marks being obtained as previously from the Shortt clock. Data have been forwarded to the collecting centres, from which regular predictions are received. Unsuccessful attempts were made to detect daylight passages of 1957β, during its final stages, by means of radio (V.H.F.) carrier-wave reflections; no really suitable transmitter is available in the British Isles.

Clocks.—The Shortt free-pendulum installation has operated without interruption throughout the year. Little progress has yet been made by the G.P.O. towards utilizing the Dunsink clock for controlling a national time-service.

ADH-Telescope and Boyden Observatory.—Dr Smyth attended a meeting in Hamburg-Bergedorf of the Administrative Council of the Boyden Observatory.

The Eichner iris astrophotometer has been overhauled and adjusted, and some exploratory measurements have been made of the plates taken by Dr H. E. Butler and Dr G. I. Thompson, of southern galactic open clusters. The necessary photoelectric scales are to be obtained with the 60-inch Boyden reflector.

Conferences.—Dr Smyth attended in Moscow the Fifth Assembly of the Special Committee of the International Geophysical Year and presented to the symposium on rockets and satellites a paper on photographic satellite tracking with 35 mm cameras. Dr Smyth and Miss McKenna attended the Tenth General Assembly of the International Astronomical Union in Moscow.

Visitors.—The public open nights were continued, on the first Saturday of each month from September to April. The 12-inch South refractor was available to members of the Dublin Centre of the Irish Astronomical Society. Visiting astronomers included Professor H. A. Brück, Drs E. J. Öpik, A. N. Argue and J. Ring.

Staff.—Professor Ellison took up his duties on November 1 as Senior Professor of Astronomy in the Dublin Institute for Advanced Studies and Director of Dunsink Observatory. Mr J. H. Reid, of the Royal Observatory, Edinburgh, was in the same month appointed to the newly-created post of Assistant, to take up duty on 1959 January 1.

In addition to the above, the scientific staff includes Dr M. J. Smyth, Chief Assistant, and Miss S. M. P. McKenna, Research Scholar.

Dominion Observatory, Ottawa

(*Director, Dr C. S. Beals, F.R.S.*)

Positional Astronomy.—The time service of Canada was maintained as usual, based on PZT observations corrected for polar wandering and annual fluctuation. Information was exchanged concerning the daily performance of quartz oscillators at the Observatory and the National Research Council. Comparisons between the rate of a new caesium resonator at NRC and the mean monthly determination of UT2 were commenced. Continuous time signals with a voice announcement each minute were broadcast on 3330, 7335, and 14670 Kc/s.

A dual rate moon camera adapted to the 15-inch equatorial, and the restored broken type Cooke transit were operated as I.G.Y. projects. A new apochromatic lens was installed in the 15″ telescope replacing a lens which had been in use for over 50 years.

The two major programmes of the meridian circle are well advanced, a further 6590 observations having been made. Design and assembly of component parts for the new mirror transit were continued.

Stellar Physics Division.—Progress was made toward the completion of the Dominion Radio Astrophysical Observatory near Penticton, B.C. The 84 ft equatorially mounted parabolic antenna was completed at the D.S. Kennedy and Company plant and the construction of the 21 cm hydrogen line receiver was begun by the Ewen-Knight Corporation. Work was begun in November on the telescope foundation, the control and office building and other site development. It is expected that the new observatory will be functioning in the autumn of 1959.

The Division contributed to the I.G.Y. in three disciplines, the data being forwarded to World Data Centres. The H-alpha solar flare patrol was operated at Ottawa on a routine basis; artificial earth satellites were photographed at Ottawa, Meanook and Newbrook; and in co-operation with the National Research Council meteors were observed visually on 36 nights.

The programme of simultaneous photography of meteor trails for height, velocity and deceleration determinations was continued at the Meanook and Newbrook Meteor Observatories. In addition, spectra of several meteors were obtained using spectrographs of widely varying dispersion. These spectra have allowed, for the first time, the identification of the auroral green line in meteor trails.

Seismological Division.—No major changes have been made in the network of permanent seismograph stations. Planning is well under way to re-locate two of the Pacific coast stations to provide a broader coverage of earthquakes in that region. Arrangements have been made to construct two new seismograph vaults north of Resolute, at present the most northerly station in the world. Electronic amplifiers have been developed to allow telemetering and magnetic recording, at both field and fixed stations, of seismic shocks. An agreement has been reached on the commercial manufacture of the bridge developed for the calibration of electromagnetic seismographs. Fault-plane studies continue to be a major activity of the division. Additional stations were laid out to make seismic refraction observations across the Cordillera from the Ripple Rock explosion in April; indications of crustal thickening under the mountains were obtained. In October, temporary seismograph stations in North-Western Ontario successfully recorded the Nevada underground nuclear tests.

Geomagnetism Division.—Magnetic Observatories were maintained at Agincourt, Ontario; Meanook, Alberta; Baker Lake and Resolute Bay, N.W.T. The I.G.Y. observatory at Victoria, B.C., operated throughout the year and plans were made to have it continued on a permanent basis while that at Yellowknife, N.W.T. was closed down in August, 1958. Plans for the building of a magnetic observatory at Alert, Northern Ellesmere Island reached a final stage. Earth current recordings continued at Meanook. Magnetic survey operations were carried out in Western Canada by ground parties. The Dominion Observatory three-component airborne magnetometer was employed in a survey of British Columbia and flights over the Pacific Ocean to New Zealand, Australia, Philippines

Japan, Alaska, and intervening islands. The construction of isogonic charts for immediate use and those for the epoch 1960·0 continued. Rock cores from suspected meteor craters were analysed by use of the astatic magnetometer and results appeared to be promising.

Gravity Division.—Further tests were carried out with the recently developed bronze bi-pendulum apparatus. Gravity ties were made between Ottawa and Winnipeg, Manitoba, and between Winnipeg and Estevan, Regina, Saskatoon and La Ronge in Saskatchewan. A programme of further development was initiated to improve the accuracy and portability of the recording and timing equipment.

The regional gravity mapping programme was accelerated. Over 1,000 stations were established in Quebec, east of Hudson Bay, by an aircraft party. The cooperative programme with the oil companies in the prairie provinces continued during the year. Some 6,000 stations have been provided by the companies; during the summer 700 of these were tied to the Dominion Observatory network by gravimeter. This has provided sufficient data to begin compilation of gravity anomaly maps on two eight-mile map sheets of the National Topographic Series.

Continuous recording gravimeters were maintained at Meanook, Alberta, and at Ottawa, for earth tide studies for the I.G.Y.

David Dunlap Observatory, University of Toronto

(*Director, Professor J. F. Heard*)

Radial velocities.—Observations have now been completed for velocity studies of 55 faint Kapteyn Area Fundamental Stars in the galactic cap. Observations and measurements have been continued for 102 faint OB stars. A selection of B-type stars from the Radcliffe velocity programme have been observed here for purposes of comparison of the systems of the two observatories.

Miss Northcott has studied the spectrographic binaries HD 19485, 154528, 174369 and 214946. Heard has studied HD 217312, a double-line binary of large mass in the Cepheus III aggregate.

Photometry.—Mrs Hogg has continued her studies of variable stars in globular clusters.

Stellar luminosities.—MacRae has obtained equivalent widths of $H\gamma$ for 65 stars using the photoelectric spectrophotometer. Searle has continued a programme of the photometry of standard stars with this instrument.

Oke has prepared an HR diagram for 185 non-cluster stars of types F5 to K2 for which accurate absolute magnitudes exist either as a result of trigonometric parallaxes or his own precise luminosity measures from spectra. He has found 16 stars which appear to be older than the stars in M67.

Searle has continued a programme of luminosity and abundance classification of 100 high-velocity F- and G-type dwarfs based on measurements of depths of lines and blended features in tracings of 33 A/mm spectrograms.

Spectra.—Searle has completed a spectroscopic analysis of three shell stars and also a study of element abundances in R Coronae Borealis.

Heard has continued observations of 53 Be stars for spectral variations.

Computation.—Demarque has written programmes for the IBM 650 for the computation of the structure of the outer convective zones in main sequence stars of about one solar mass and of arbitrary composition, and has begun to construct accurate stellar interior models for homogeneous stars of various compositions.

Galaxies.—van den Bergh has studied the influence of gas density on the rate of evolution of galaxies, finding that a high initial gas density gave rise to a galaxy in which the initial rate of star formation was high and which now has exhausted its interstellar gas and contains predominently old stars.

van den Bergh has developed for late-type spiral galaxies a preliminary luminosity classification system which is based on the strong correlation between absolute magnitude and degree of development of spiral structure. Using the prints of the Palomar Sky Survey he has investigated the distribution of dwarf galaxies, finding a strong concentration of nearby dwarf irregular galaxies in the vicinity of M94 in Canes Venatici.

Clusters.—Mrs Hogg has prepared several summarizing articles from her extensive bibliographical material on clusters.

van den Bergh is engaged upon a study of the luminosity function for about 30 galactic clusters from a series of 172 48-inch Palomar Schmidt plates obtained in 1958. He is also collaborating with Sandage in a study of the old galactic cluster NCG 188.

Radio astronomy.—The joint programme with the Department of Electrical Engineering for the absolute measurement of radio flux is continuing. The solar radio flux is measured daily at noon with the horn antenna at 320 Mc. Also at this same frequency preliminary observations by an interferometer technique of the flux from Cassiopeia A have been obtained. Problems in antenna design and the development of parametric amplifiers for use at centimetre wave-lengths are being investigated. This work is under the direction of MacRae and Yen.

Staff.—Professor J. B. Oke resigned to accept a post at the Mount Wilson and Palomar Observatories. Dr S. van den Bergh joined the staff as Lecturer. Dr W. Buscombe was visiting lecturer for the Michaelmass term.

Publications.—Since the last report, Communications D.D.O. No. 42 has been issued.

Dominion Astrophysical Observatory, Victoria

(*Director, Dr R. M. Petrie*)

Staff.—Dr J. A. Pearce retired on April 1 after a period of thirty-four years continuous service, including ten years as Director. E. K. Lee continued on education leave at the University of Michigan. National Research Council Fellows R. Wilson and R. S. Kushwaha terminated their appointments and C. R. Lynds, of the Berkeley Astronomical Department, commenced tenure of a Fellowship in November. E. G. Ebbighausen, of the University of Oregon, began his tenure as visiting Fellow of the National Science Foundation, U. S. A., in September. Seasonal appointments were held by J. L. Climenhaga and G. E. Cross of Victoria College; and R. L. Hemmings, S. C. Morris, B. R. Parker and A. Perry-Whittingham, all of the University of British Columbia.

Spectroscopy.—Much attention continued to be devoted to the ζ Aurigae-like stars, high dispersion spectrograms having been made of 31 Cygni, VV Cephei and ε Aurigae. K. O. Wright has completed the analysis (mentioned in the last report) of the chromospheric spectrum of 31 Cygni as photographed at the 1951 eclipse. The temperature and pressure changes already announced are confirmed and a sharp change in density gradient, some 10^7 km from the limb of the star, suggests a two-layer atmosphere. Theoretical work by G. J. Odgers indicates that the inner chromosphere is effectively blanketed from the ionizing radiation of the B-type component. A study of the *K* line of ionized calcium in the spectrum of 31 Cygni at the 1951 eclipse has been completed by McKellar, Aller, Odgers and Richardson. Intensity and radial velocity variations are given as well as evidence of structure in the line and a comparison of the observed and the computed profiles.

High dispersion spectra of VV Cephei have been obtained between wave-lengths 3200 and 6800. Fourth contact appears to have occurred late in January. The chromospheric absorptions became narrower and weaker after fourth contact but were still visible at the end of the year. Radial velocities from high dispersion spectra of ε Aurigae made between 1955 and 1958 are studied by K. O. Wright. Normal lines show a velocity change from +10 km/sec to −10 km/sec during the interval mentioned above. The radial velocities of chromospheric lines vary from +10 to +25 before totality and from −20 to −40 after totality. The chromospheric lines are detected a full year outside eclipse and are sometimes complex in " totality ".

A. B. Underhill has obtained spectra of the Wolf-Rayet stars HD 192103, WC7, and HD 192163, WN6, between wave-lengths 3150 and 6750. The ultra-violet region especially has permitted an extension of our knowledge of wave-lengths and identifications. Strong doubts are cast upon the hypothesis of two parallel mutually exclusive sequences. While the WN6 spectrum is dominated by lines of He II, N III and N IV, weak lines of O III, O IV and O V occur, as well as the well-known line of C IV at 5806. Similarly the WC7 spectrum is dominated by lines of the He I, He II, C II, C III and C IV but there are also lines of O III, O IV, O V and N III, and possibly N IV. The distribution of light in W spectra has been estimated by comparison with those of 10 Lacertae and HD 192639, a reddened O star. The W spectra are found to be at least as blue as 10 Lacertae and the low colour temperatures previously found from spectra covering a relatively short region must be revised upward.

J. K. McDonald has continued measuring absorption lines in B spectra made with moderate dispersion. Lines in the spectra of over 100 stars have been measured in the spectral region K to Hβ. Preliminary plots of line strengths and line ratios against HD and MK spectral types show a large scatter. They will, however, serve as a basis for the assignment of spectral type.

G. J. Odgers continues the study of β Cephei stars. Radial velocities have been measured on about 100 high dispersion spectrograms of β Cephei obtained at Mt Wilson. New spectroscopic observations of complete cycles have been made of several β Cephei variables.

A. McKellar and J. L. Climenhaga have calculated the profiles of the main and isotopic bands of C_2 taking into account the curve-of-growth effect. The results when applied to observed profiles in R-type spectra will double the previously deduced ratio of the relative abundance C^{12}/C^{13}. The ratio C^{12}/C^{13}

now is considered to be 6 for R spectra, showing the high carbon-isotope abundance.

A. B. Underhill has continued her study of the spectrum of the O star 9 Sagittae. Intensities of a large number of lines are being derived and these so far support the hypothesis that a shell spectrum is observed. The radial velocity varies irregularly through some 30 km/sec. The emission at Hα varies from year to year.

The computation of theoretical spectra of B type stars undertaken by A. B. Underhill continues to make progress. Programmes have been prepared for the digital computer at the University of British Columbia for the computation of the source functions and fluxes for atmospheres with scattering and absorption.

Stellar motions.—Radial-velocity observations were made during the year of faint B stars, visual and spectroscopic binary stars, β Cephei variables, and members of galactic clusters. Some 1,500 spectrograms were measured for radial velocity, mostly by Ebbighausen, Odgers, Petrie and Underhill. R. M. Petrie has compiled a catalogue of radial velocities of faint B stars observed at Victoria during the past fifteen years. This extensive programme gives stellar and interstellar velocities of some 550 stars, mostly not observed elsewhere. A few observations are still required to complete the work.

J. K. McDonald has measured up to date radial velocities of stars in the neighbourhood of the Praesepe Cluster. A. B. Underhill has measured radial velocities of faint stars in 5 galactic clusters.

Binary stars.—E. G. Ebbighausen and R. M. Petrie continued to observe spectroscopic binaries to investigate changes in orbital elements. Second epoch " orbits " have been obtained for 5 systems and third epoch observations for 4 systems. Observations for additional new orbit determinations have been obtained of 57 Cygni and AR Cassiopeiae. Definitive orbital elements of HR 8800 from observations made in 1919 and in 1957–8 show an advance in ω of $90^\circ{\cdot}0 \pm 8^\circ{\cdot}4$ giving the apsidal period as 154 ± 14 years.

A. B. Underhill continues to obtain radial velocities of 8 visual binary systems. The system ϵ Hydrae (period = 15·3 years) shows a radial velocity variation of small amplitude in a period thought to be about 70 days.

Seismology.—The Seismology Division, in charge of W. G. Milne, continued to operate the Western Canada network and to inspect the records. Land explosion experiments have been carried out to determine local crustal speeds of seismic waves in order to supplement the depth charge programme. One hundred and forty-four local earthquakes were recorded in 1958.

The successful demolition of Ripple Rock on April 8 by the greatest conventional explosive blast was recorded at a number of stations in western Canada. The results are now under analysis.

International Geophysical Year.—Installations under this programme continue to be operated by B. Caner. Added since the last report are an air sampler for airborne fission products and a special camera and time signal recorder for observations of artificial earth satellites. Some 70 direct photographs of satellite $1958\delta_1$ and $1958\delta_2$ have been obtained and measured by P. E. Argyle, D. H. Andrews and S. H. Draper.

Instrumentation.—Construction of a dome and building to house the 48-inch reflecting telescope and coudé spectrograph began in mid-February and is essentially completed at the end of the year. Work progresses on the telescope itself.

Some of the heavy parts of the mounting have been partly fabricated and the main mirror is roughed out. During the year an Observatory workshop was completed and occupied.

A new measuring machine with a screw of 25 cm travel and a 1 mm pitch has been transformed to a projection measuring machine and is now in use in the measurement of spectrograms.

During the year D. H. Andrews designed and constructed, with the help of the shop staff, a machine for producing reductions to the Sun for radial-velocity measurements. This mechanical device has now been in operation for some months and has proved itself to be accurate and reliable. It has greatly reduced the labour of obtaining reductions to the Sun.

The shop staff carried out all necessary maintenance and repairs to the equipment in the dome and office building and designed and constructed numerous pieces of auxiliary equipment for the telescope.

Publications.—The following papers were submitted for publication:

Publications

Vol. XI, No. 3. " The B-Type Secondary Spectrum and Atmospheric Effects Observed at the 1951 Eclipse of 31 Cygni " by K. O. Wright and E. K. Lee.

Vol. XI, No. 5. " A Wave-Length Study of the Spectrum of HD 188001, 9 Sagittae " by A. B. Underhill.

Vol. XI, No. 6, " Shock Waves in the Atmosphere of the β Cephei Star BW Vulpeculae " by G. J. Odgers and R. S. Kushwaha.

Contributions

No. 61. " A Re-examination of the Space Motions and Luminosities of the Stars of the Cassiopeia-Taurus Group Based upon New Radial Velocities " by R. M. Petrie.

No. 62. " An Instrument for Calculating Precession " by D. H. Andrews.

No. 63. " Observations of Broad Interstellar Features at $\lambda\lambda$ 4430, 4760, 4890, 6190 " by R. Wilson.

No. 64. " The Relation Between Interstellar Extinction and Polarization " by R. Wilson.

A. McKellar prepared a chapter entitled " Isotopes in Stellar Atmospheres " for Volume 6 of the forthcoming Compendium of Astronomy and Astrophysics. R. M. Petrie prepared an article entitled " Stellar Radial Velocities " for the forthcoming Dictionary of Physics.

Union Observatory, Johannesburg

(*Director, Dr W. S. Finsen, Union Astronomer*)

Staff.—Mr J. Churms, Assistant Professional Officer, resigned on 1957 December 31 to take up an appointment at the Royal Observatory, Cape. Mr G. F. G. Knipe was appointed Professional Officer on May 26. Miss E. M. Bernardy, Library Assistant, resigned on January 31 and Mr W. J. F. Nel was appointed Library Assistant on February 1. Miss D. M. Howe was transferred on July 31 and was succeeded by Mrs A. R. Canavesio on September 29.

Additional posts of Professional Officer and Clerical Assistant were authorized during the year but remain unfilled; two other professional posts were vacant throughout the year.

It is a pleasure to acknowledge again the valuable help rendered by the group of amateurs associated with the Observatory, especially Messrs. H. C. Lagerweij, J. H. Botham, I. R. H. Brickett, M. D. Overbeek, C. N. Williams, A. Johnston, J. Vollmer. Without their loyal support and assistance this would indeed have been a difficult year.

Instrumentation.—The Markowitz Dual Rate Moon Camera was found to require alterations and modifications which were carried out as time permitted during the year, but it was not found possible to bring it into regular use.

Five "Apogee" telescopes for observation of faint artificial satellites were obtained on loan through the South African National Committee for the I.G.Y.

Astronomical research.—The 26½-inch refractor was used by Finsen for short periods on 124 nights, principally for interferometer measures of double stars. Towards the end of the year Knipe began a programme of micrometer observations of double stars and obtained 31 measures on 13 nights.

The Franklin Adams Telescope at Hartbeespoort was used by Bruwer on 22 nights and 185 plates were obtained, mainly of minor planet fields.

With the 9-inch and Franklin Adams Twin Telescopes 8 occultations were observed, while physical observations of Jupiter, Saturn and Mars were made on 49, 33 and 27 nights respectively; the principal observers were Brickett and Botham. In addition Knipe used the 9-inch telescope on 46 nights for photoelectric photometry of δ Indi, Saturn, RS Ophiuchi, Parthenope and the Moon. Meteor counts were made with "Moonwatch" telescopes on 9 nights by Botham, Vollmer, Overbeek, Johnston and Mrs Johnston.

Artificial earth satellites.—Attempts were made to observe artificial earth satellites on 347 occasions, 134 of which were successful. Staff members took part in most sessions of the "Moonwatch" team and in addition prepared predictions and carried out most of the clerical work. Close contact was maintained with the Baker-Nunn Camera Station at Olifantsfontein under the direction of Mr R. C. Cameron.

Time service.—Seligmann remained in sole charge of the Time Service with occasional assistance from other members of the staff.

In August a notable advance was made in the distribution of accurate time in the Union with the commencement of continuous transmission of time signals and standard frequencies by the Post Office transmitting station at Olifantsfontein, with a power of 4 kilowatts. Both the 5 Mc/s carrier frequency and the modulation frequencies are controlled by one of the standard oscillators at the Observatory through a 100 Mc/s VHF link. The Observatory's low-power transmitter ZUO now operates on a frequency of 10 Mc/s; a Techrad transmitter with a power of 200 watts was acquired during the year to replace the transmitter formerly in use.

ZUO time and frequency deviations have from the beginning of the year been published monthly in the *Transactions of the S.A. Institute of Electrical Engineers.*

Publications.—*Union Observatory Circular* No. 117 and six time signal and standard frequency bulletins were issued during the year.

Civil astronomy.—The popular demand for artificial satellite predictions in addition to normal routine duties severely taxed the Observatory's resources.

The Observatory was open to the public on 23 nights and as in previous years amateurs gave invaluable help as demonstrators and guides.

The Union Astronomer was an official delegate to the Fifth Meeting of C.S.A.G.I. and the Tenth General Assembly of the I.A.U. held in Moscow in July and August.

Radcliffe Observatory, Pretoria

(*Director, Dr A. D. Thackeray, Radcliffe Observer*)

1. *Equipment.*—Optical and mechanical parts of the Coudé spectrograph by Messrs Cox, Hargreaves and Thomson Ltd were received in Pretoria during the latter half of 1958. Provisions for mounting the main frame at the Coudé focus of the 74-inch reflector are being constructed locally. Thermostat control has been added to the coudé hut despite the efficient insulation of the walls which renders the diurnal temperature range quite small. A new 8 × 6-inch Bausch & Lomb grating has been received to replace the original, which showed certain defects in final tests of the complete spectrograph.

The aluminizing tank for the 74-inch mirror has been successfully used for preliminary tests. Aluminizing of the 74-inch mirror has had to be postponed, however, as a result of revised plans for the mechanical process of removal from the cell.

The protective wind screens in the turret have been thoroughly overhauled and provided with new chains.

A Sartorius iris diaphragm photometer has been ordered and is expected to be received early in 1959.

2. *Spectroscopy.* (*a*) *Galactic radial velocities.*—Observations of distant B stars, with emphasis on certain clusters and associations (especially IC 2944), have been continued. Selected stars in the region 17^h to 19^h R.A. are being observed in common with the David Dunlap Observatory.

Work on members of the cluster NGC 3293 has been completed and included in a paper to appear in *Monthly Notices.* 112 spectra of 35 stars were obtained. The HR diagram is that expected for a young cluster. The radial velocities show an unexplained dependence on magnitude.

The programme on southern long-period variables has been extended to include some very faint distant variables in the direction of the galactic centre (selected from *Leiden Ann.*, XX).

Dr Kinman's observational programme on southern globular clusters has been completed, the Cassegrain material being supplemented in 1958 by 36 Newtonian spectra of 12 globular clusters. An analysis of the motions of 70 clusters is essentially complete. The study includes discussion of spectral types of clusters and individual stars.

Dr Kinman has also obtained 178 Cassegrain spectra of 19 RR Lyr variables of which only three had been previously observed by Joy. In this programme 45 spectra have been obtained of standards for spectral type and wavelength.

(*b*) *Magellanic Clouds.*—Spectroscopy of bright members of both Clouds has been continued vigorously. A report (*Observatory*, 78, 156, 1958) was

presented at the IAU Symposium on the Hertzsprung Russell diagram. It is planned to publish at the end of the current season data on spectral types and radial velocities of a substantial number of Cloud members, and also to list the foreground non-members which have been detected in the course of this work.

Absorption by Ca II gas arising within the Galaxy and within both Clouds has been detected in the spectra of Cloud members. Luyten's proper motion star CPD $-69°389$ has been found to be a non-member projected on the Large Cloud; it is the first instance of a foreground star classified in the HDE as " B ".

Through the cooperation of Dr E. M. Lindsay, a number of his ADH objective prism spectra of the Small Cloud have been made available on loan. On these plates a number of Cloud members (not in the HD Catalogue) have been detected. Examination with the Cassegrain spectrograph has been postponed pending completion of the former programme.

(*c*) *Individual stars.*—Eta Carinae: further spectra of portions of the surrounding halo have been obtained.

RR Tel: [Fe VI] emission has been very strong in 1958, and [Fe VII] has also appeared in accordance with expectations.

RS Oph: a series of spectra showing the emergence of various forbidden lines (including coronal lines) was obtained following the July maximum. A table of estimated intensities on various dates is included in a note to *Observatory* (Griffin and Thackeray, in press).

θ Oph: two series of spectra covering cycles of this β C Ma variable were obtained for Dr A. van Hoof.

Eclipsing variables studied spectroscopically include GL Car, W Cru, AI Cru, RS Ind, AR Pav, BO Pav, SW Phe, RT Scl, V 523 Sgr, V 526 Sgr, AL Vel, AO Vel.

3. *Direct photography.*—Further plates of the LMC globular clusters NGC 1978, 2257 known to contain variables were obtained. Visual plates were obtained of NGC 1866 for a 2-colour study of the 3-day Cepheids (in cooperation with Dr A. Sandage).

Many southern galactic clusters have been photographed for survey purposes.

The faint variable star on the edge of a globule in IC 2944 reported to the Liège 1954 symposium has brightened again. A second faint variable (apparently unconnected with a globule) has been found in another part of this cluster.

The minor planet Icarus was photographed on two nights at an unusually favourable opposition, the plates being measured at the Royal Observatory, Cape. (Kinman *et al.*, *M.N.A.S.S.A.*, XVII, 70.)

4. *Photoelectric photometry.*—3-colour observations have been continued of members of both Magellanic Clouds, including a selection of stars in NGC 371. The combination of $B-V$ colours with Radcliffe spectral types proves the existence of absorption in front of stars in both Clouds. Photoelectrically, as well as spectroscopically, no outstanding differences between the Cloud and galactic supergiants have been detected. The reliability of the system has been ensured by observations of standard stars in the region of the Clouds and in E regions on every night. Observations of some Hiltner stars in the Galaxy and of Johnson stars in and near IC 4665 have been secured in order to study the relation of the Radcliffe observations to the *UBV* system.

Work on the periods and median apparent magnitudes of the numerous variables in NGC 1466 has been continued.

In the Galaxy, 3-colour observations have been made of stars in the clusters IC 2944, NGC 6067, 4103, 3532.

Further observations have been made of the polarization of portions of the halo around Eta Carinae; colours and magnitudes of stars in this region are also being studied.

Further observations have been made of some stars in 47 Tuc to strengthen the sequence for a study of the colour-magnitude array. Through the cooperation of Dr H. C. Arp, Radcliffe plates of 47 Tuc are being measured with an iris diaphragm photometer at the Mt Wilson and Palomar Observatories.

5. *D.S.I.R. grant.*—As a result of representations by the Astronomer Royal, a 5-year grant from the Department of Scientific and Industrial Research to the Radcliffe Trustees has been approved. The main purpose of the programme is a comparison of the Magellanic Clouds and the Galaxy and more particularly an extensive study of Cepheids and clusters in two areas of the Large Magellanic Cloud (Shapley Constellation III and another centred near NGC 1783).

Photoelectric sequences in these two regions (to $V = 17{\cdot}2$ and $18{\cdot}3$ respectively) have been set up by Dr O. J. Eggen with equipment brought by him. A faint sequence near NGC 121 and 47 Tuc is also being set up. Zero point and colour equation were determined from bright stars in both Clouds, which were independently tied into northern standards with the 18-inch reflector at the Cape Observatory.

Series of direct photographs in two colours have been obtained with the 74-inch reflector by Dr A. Sandage of a number of clusters in the two fields, notably NGC 1783, 1818, 1761. The photoelectric sequences will be used to obtain colour-magnitude arrays from these plates. NGC 121 will be studied similarly.

Plates for two-colour light-curves of Cepheids in the two areas have been obtained by Mr J. B. Alexander at the Royal Observatory, Cape. Magnitudes will be interpolated from the photoelectric sequences. A large number of variables have been detected by blinking these plates.

As an associated part of the scheme a study of RR Lyr variables has been undertaken by Dr T. D. Kinman.

Part of the grant has been used to provide necessary extra office accommodation and some ancillary equipment at the Radcliffe Observatory (especially an iris diaphragm photometer).

6. *Buildings and grounds.*—An additional office has been built with provision for accommodating the iris diaphragm photometer.

Following a very dry winter a severe fire swept through trees and grass for about 6 hours in October. The Pretoria Municipal Fire Brigade gave outstanding assistance in extinguishing it, and none of the buildings was ever in serious danger.

7. *General.*—The problem of standard coordinates in both Magellanic Clouds has been studied, and formulae have been derived for computing right ascension and declination from Harvard x and y coordinates.

In connection with the interpretation of the observations of the halo around Eta Carinae, various forms of scattering have been considered. The application of Hubble's law to reflection nebulae has been studied.

In a season of about average quality the telescope was used on 289 nights, being out of action for 3 nights in the year for resilvering.

8. *Guest investigators.*—One third of the telescope time was allocated as usual to astronomers from the Royal Observatory, Cape. Dr A. Muller (Leiden Southern Station) observed southern B stars spectroscopically for radial velocities, including some members of the Scorpio-Centaurus group for F. Bertiau. From September, Dr O. J. Eggen (Royal Greenwich Observatory) and Dr A. Sandage (Mt Wilson and Palomar Observatories) worked on the Magellanic Clouds, as described in Section 5 above.

9. *Staff and visitors.*—Dr T. D. Kinman's Radcliffe Fellowship expired in September, but he continued work at the Observatory, on RR Lyr variables, under the D.S.I.R. scheme.

Visitors, in addition to those mentioned in Section 8, using the 74-inch telescope were as follows: from the Royal Greenwich Observatory, R. v. d. R. Woolley; from the Royal Observatory, Cape: J. Churms, D. S. Evans, R. Lake, T. W. Russo, P. A. Wayman (seconded from the Royal Greenwich Observatory).

It was a particular pleasure to welcome the Astronomer Royal to the Observatory during December. Other visitors to the Observatory during the year included R. C. Cameron, D. W. Dewhirst, M. A. Ellison, R. Griffin, H. Haffner, P. Hodge, J. A. Hynek, L. Loden, R. H. Stoy and R. V. Willstrop.

Dr M. W. Feast represented the Observatory at the Moscow General Assembly of the International Astronomical Union, where he reported on Magellanic Cloud work to the Symposium on the Hertzsprung-Russell Diagram. He also read a paper at the summer meeting of the Society at Keele Hall and visited Observatories in U.K.

Nizamiah Observatory, Hyderabad

(*Director, Dr Akbar Ali*)

Astrographic equatorial.—The 8-inch photovisual object glass of the astrographic telescope arrived back after repairs in September 1958. No photographic work was possible on account of non-availability of 16 cm × 16 cm photographic plates due to import restrictions. The authorities concerned have been approached for the grant of an import licence for these plates.

The work of deriving proper motions of stars in the regions common to the Oxford astrographic catalogues and the Potsdam Himmelskarte catalogues (zones $+32°$ and $+33°$) continued during the year. A list of 382 relative proper motions with corrections for reduction to absolute motions was prepared by A. N. Goyal. Another list of proper motions from R.A. 3^h9^m to R.A. 5^h1^m in the same zones is being prepared by S. Aravamudan.

9 astrographic plates of the Observatory were loaned in October 1958 to the Astrometric Department of the Royal Greenwich Observatory for deriving the proper motions of stars in the Lacerta aggregate.

Grubb equatorial.—16 occultations of stars by the Moon were observed and communicated to the Nautical Almanac Office for inclusion in the annual discussion.

Dr Gordon E. Taylor of H. M. Nautical Almanac Office kindly supplied telegraphically data concerning the possible occultation of the northerly component of the double star ADS 7910 by Pluto on 1958 November 20. The occultation however could not be observed owing to cloudy weather.

Spectrohelioscope.—The Observatory continued its participation in the I.G.Y. programme in observations of solar flares and related phenomena.

The Sun's disk was observed in Hα on 228 days for about 2^h30^m on average per day. 91 flares were observed. Their distribution in importance was 1 in 3, 1 in 2^+, 10 in 2, 20 in 1^+, 42 in 1 and 17 in 1^-.

77 dark filaments with 28 positive shifts, 25 negative shifts and 24 shifts both positive and negative were also observed. 33 prominences with 6 positive shifts, 15 negative shifts and 12 both positive and negative were noted.

The data of solar observations have been communicated to the three World Centres at Colorado, Meudon and Moscow and are being published in the Annals for I.G.Y. for 1957–58. The average overall seeing conditions of the sky for solar observations for the year were: 84 days of seeing 1, 123 days of 2 and 21 days of 3 in the scale 1 for poor and 3 for good seeing. Spectrohelioscope observations were taken by Habeeb Alvi for 346 hours and by B. Narasimhan for 208 hours.

The Physical Laboratories, Osmania University, initiated a programme of radio surveying of the sky at 30 mc/s in 1957 under the supervision of Dr Krishnamurthi. A 30 element aerial array having a width of 8° in the E–W direction and 18° in the N–S direction between half power points was installed in the Physical Laboratories for this purpose. Dr Krishnamurthi after joining the Observatory is continuing the radio survey in collaboration with the Physical Laboratories. During the months of May to August 1958, solar radio emission at 30 mc/s was studied and different types of enhanced radio emission were recorded.

An atmospheric receiver was constructed and a 50 ft aerial installed locally in March 1958 for studying the sudden increase in atmospherics caused by solar flares. It is intended to acquire an Evershed Recorder as soon as the necessary foreign exchange is made available. The Observatory is deeply indebted to Dr M. A. Ellison of Royal Observatory, Edinburgh, for having supplied the technical data for the construction of the atmospheric receiver.

Publications.—The following papers were sent for publication:

(1) " Stars with large proper motions in the astrographic zones +32° and +33° List III " (*Journal des Observateurs*); (2) " Radio emission from the Sun at 30 Mc/s " (*Journal of Scientific and Industrial Research*); and (3) " Stars with large proper motions in the astrographic zones +32° and +33°, List IV " (*Journal des Observateurs*).

Staff.—As mentioned in the report for 1956, a department of astronomy is being established in the Osmania University. Under this scheme, Dr M. Krishnamurthi was appointed Reader/Astronomer in June 1958 and Dr M. B. K. Sarma as Lecturer/Assistant-Astronomer in December 1958.

Equipment.—The contract for the construction of the 48-inch parabolic reflector was finalized with J. W. Feckers, Inc., U.S.A. The requisite mirror blank has been secured. It is reported that the mirror blank shows some unrelieved stresses by polarized light. The defect is being remedied by the firm in consultation with specialists from Corning Glass Works, U.S.A.

My grateful thanks are due to Dr J. J. Nassau, Director, Warner & Swasey Observatory for having kindly consented to supervise the optical performance of the reflector on our behalf.

Among the instruments which arrived from U.S.A. during the year may be mentioned a Gaertner Star Coordinate Comparator, two Gaertner Linear Comparators, all reading to 0·001 mm and an Eichner iris diaphragm astrophotometer. These machines were re-assembled and installed by Dr Krishnamurthi. The astrophotometer was slightly damaged during transit and is still under adjustment.

Dr Krishnamurthi is engaged in the design of a photon-counting photometer for use in conjunction with the 15-inch Grubb refractor.

One Boley lathe machine (height of centres 120 mm and distance between centres 450 mm), one Martin lathe machine (height of centres 178 mm and distance between centres 1500 mm) and one universal type Christen milling machine from Europe were added to the equipment of the Observatory workshop in December 1958. These machines are under assemblage and installation.

Building.—Plans for the construction of the astrophysical laboratory for the proposed Department of Astronomy in the Osmania University campus are ready and the construction will be taken on hand probably early next year.

Library.—Orders have been placed through the India Wheat Loan Office for the purchase of the second edition of the Mt Palomar Sky Atlas and its extension to $-30°$ declination zone.

5 books were purchased and 20 journals were subscribed for during the year. 1108 publications were received on exchange basis from various observatories and scientific institutions.

Visitors.—Dr Maud W. Makemeon, formerly Director of Vassar College Observatory, New York, paid a visit to the Observatory in July 1958.

650 visitors, including students from colleges and other educational institutions, visited the Observatory and were shown objects of interest.

Miscellaneous.—Lectures in practical astronomy were delivered to the graduate classes of the Osmania University.

The other routine work, such as preparing the official calendar, seismological work, etc., continued as usual. The Observatory is cooperating in the I.G.Y. programme in seismological work also.

Kodaikanal Observatory

(*Director Dr A. K. Das*)

General.—The major optical components for a Lyot monochromatic heliograph were received from France; and the construction of the mechanical parts for the heliograph in our own workshop and the assembly of the optical components were completed. The 8-inch Lyot coronagraph ordered from France and the large solar telescope ordered from England were received in October. The construction of a 60-ft spectrograph to work with the solar telescope was begun. The dome and the underground tunnel for housing the solar telescope and the spectrograph and the dome for the coronagraph and the monochromatic heliograph were still under construction. The installation of these new instruments will begin as soon as the Public Works Department has completed the buildings.

One Danjon earth-light photometer constructed for this observatory by the Pic-du-Midi Observatory was received, and regular observations with this instrument will begin shortly.

The I.G.Y. programme of intensive observations (solar, geomagnetic, ionospheric, ozone, auroral and meteorological) was continued during the year. The solar data were sent periodically to the World Data Centres. Ionospheric data, including *f*-plots for RWDs and SWIs and complete magnetic data were prepared for transmission to the appropriate World Data Centres.

An Askania field balance for vertical force with normal speed and quick-run recorders was received and installed. Quick-run records of vertical force were also made in addition to those of horizontal force on RWDs and SWIs.

Messages in I.G.Y. code for daily broadcasts of Kodaikanal observations by the All-India Meteorological Broadcasting Centre and plain language messages for inclusion in the special I.G.Y. broadcasts by the All-india Radio were sent daily to New Delhi.

Observations of ' seeing conditions ' made during the last few years at Ujjain in Central India and at Kaliadeh (in the open country outside Ujjain) showed that this area would be suitable for the establishment of a large modern astronomical observatory. The proposal for the establishment of the observatory which had previously been included in the Second Five-Year Plan was however postponed for the time being.

Scientific Cooperation.—Exchange of spectroheliograms with foreign observatories was continued. For the period July 1957–June 1958 52 H-alpha disk and 59 K-disk spectroheliograms were received from the Meudon Observatory and for the period July–December 1957 55 H-alpha disk, 68 K-disk and 68 K-prominence spectroheliograms from the Mt Wilson Observatory. Copies of daily spectroheliograms (disk in H-alpha and K and limb in K) were supplied in fortnightly batches to the Fraunhofer Institute, Germany, for the preparation of daily solar maps.

3 photoheliograms together with the relevant zero plates for certain specified days in 1957–1958 were supplied to the Astronomer Royal, Royal Greenwich Observatory, England.

Quarterly statements relating to solar flares were sent, as in previous years, to the Meudon Observatory and to the Royal Greenwich Observatory.

Periodical statements of observational data concerning solar flares, relative sunspot numbers, ionospheric parameters and sudden ionospheric disturbances, information relating to central meridian passage of important sunspots and forecasts of expected magnetic and ionospheric disturbances were supplied to a number of interested institutions in India.

The Observatory continued to supply the monthly median values of foF2 and (M3000)F2 to the C.R.P.L., Colorado, U.S.A.; quarterly statements of monthly median values of all ionospheric parameters to the above institution and to the Radio Research Station, Slough, England; quarterly magnetic storm data to Professor John A. Simpson of the University of Chicago; and monthly statements of mean hourly values of the horizontal component of the geomagnetic field (between $15^{h}00^{m}$ and $24^{h}00^{m}$ U.T.) to Professor J. Bartels of the University of Göttingen, Germany.

Routine observations.—Photoheliograms were made on 278 days and visual observations were possible on 275 days compared to 282 and 278 days respectively in 1957. H-alpha disk, K-disk and K-prominence spectroheliograms were secured on 273, 264 and 257 days as against 261, 259 and 258 days respectively in the previous year. Observations with the spectrohelioscope were made on 263 days.

The average definition of the Sun's image on a scale in which 1 is the worst and 5 the best was 3·1. There were 56 days on which the definition was 4 or better.

Sunspot activity.—Sunspot activity during the current cycle reached its maximum in 1958. The mean latitude (for the year) of all the observed spot groups in the northern and southern hemispheres was 18°·1 and 16°·2 respectively as against 19°·2 and 18°·9 for the previous year. Details of sunspot observations are given in the following table :—

Month		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
No. of new spot-groups	N	23	14	21	33	29	20	24	24	19	18	32	27	284
	S	24	15	16	25	16	18	17	20	23	24	23	15	236
Mean daily no. of spot-groups		11·90	7·87	8·16	11·36	10·21	5·05	9·93	11·17	10·19	9·94	9·25	10·00	9·59
Kodaikanal daily relative sunspot number		226·9	144·5	200·2	220·7	166·5	189·3	201·6	211·3	207·0	178·5	168·3	198·8	192·8

Solar flares.—23 solar flares were observed during the year, 17 of intensity 1 and 6 of intensity 2.

Radio astronomy.—Construction of a receiver for the observation of solar noise on 60 Mc and of a new 100 Mc receiver was completed.

Geomagnetic observations.—Continuous photographic recording of *H*, *Z* and *D* with Watson and La Cour magnetographs and ink-recording of *H* with an Askania field balance were continued. Ink-recording of *Z* with another Askania field balance was started during the year. Values of *H*, *D* and *Z* were determined weekly with a set of QHM (Nos. 254, 255 and 256) and BMZ instruments. Absolute measurements of *H* with a Kew magnetometer and those of inclination with a Schulze Earth Inductor were also made once every month. During the year 27 magnetic storms including 25 storms of SC type were recorded with ranges in HF between 163γ and 813γ.

Ionospheric observations.—Round-the-clock ionospheric vertical incidence soundings and the recording of field-intensity were continued.

Cosmic ray, ozone, seismology and meteorology.—Regular observational work in these fields was carried out as usual.

Library.—32 books and 2479 periodicals were added to the library.

Research work.—Under the Research Training Scheme sponsored by the Ministry of Education of the Government of India, four Senior Research Scholars were working in the Observatory.

The following problems in astrophysics and geophysics were under investigation:

1. Determination of absolute values of the wavelengths of solar spectrum lines in order to determine how much of their red-shifts can be accounted for by the theory of relativity.
2. Detection of ' deuterium ' on the Sun.
3. Study of the distribution of intensity in the various features of the Sun's disk with the help of a Moll thermo-couple and thermo-relay.
4. Simultaneous measurement of temperature and magnetic field of sunspots.
5. Distribution of calcium flocculi on the Sun's disk.
6. Further study in the scattering of radio waves by ionospheric F-layer and some related geomagnetic phenomena.

7. The behaviour of night-time sporadic E-layer at Kodaikanal.
8. Solar cycle variations of F2 layer geomagnetic distortion at Kodaikanal.
9. The diurnal variation in the sizes of SC's and SI's at Kodaikanal.
10. Solar flare effects on F2 layer critical frequencies.

The following technical reports and research papers were published or communicated for publication :—

(1) Quarterly synopses of results of solar, magnetic, ionospheric and ozone observations, *Indian J. of Met. and Geophys.*
(2) Annual Report of the Kodaikanal Observatory for 1957.
(3) Reports to the Society on the work of the Kodaikanal Observatory and on prominence activity during 1957, *M.N.*, **118**, 358 and 391, 1958.
(4) *Kodaikanal Observatory Bulletin No.* 150, Summary of results of solar, magnetic and ionospheric observations for the first half of 1957.
(5) *Kodaikanal Observatory Bulletin No.* 151, " Variation of F2 layer ionisation with solar activity at Kodaikanal on magnetically disturbed and quiet days ".
(6) *Kodaikanal Observatory Bulletin No.* 152, " The solar cycle and the associated behaviours of sunspots and prominences ".
(7) *Kodaikanal Observatory Bulletin No.* 153, " Magnetic field of the planet Venus ".
(8) *Kodaikanal Observatory Bulletin No.* 154, " Opposition of Mars in 1954 and 1956 ".
(9) *Kodaikanal Observatory Bulletin No.* 155, Summary of results of solar, magnetic and ionospheric observations for the second half of 1957 including special observations taken in connection with the I.G.Y.
(10) " Sudden commencements and impulses in Kodaikanal magnetograms; their hourly frequency ", *Indian J. of Met. and Geophys.*
(11) " Annual wave in the worldwide F-region ionisation ", *Indian J. of Met. and Geophys.*
(12) " Ionospheric disturbances associated with magnetic storms at Kodaikanal ", *Indian J. of Met. and Geophys.*
(13) " Sunrise effect in the F-region of the ionosphere over Kodaikanal ", *Indian J. of Met. and Geophys.*

Uttar Pradesh State Observatory, Naini Tal

(*Director, Dr M. K. Vainu Bappu*)

Stellar spectroscopy.—Wavelengths and equivalent widths have been measured on high dispersion spectra for six of the brightest Wolf-Rayet stars in the northern hemisphere. Equivalent widths have also been measured for prominent lines from low dispersion spectra taken of all Wolf-Rayet stars north of declination -21° and brighter than magnitude 10·5. Profiles of the Balmer lines in absorption in the spectrum of the Wolf-Rayet eclipsing binary HD 193576 have been obtained both at primary minimum and out of eclipse. These have been measured in an effort to study the electron scattering envelope around the Wolf-Rayet star.

Much progress has been made in the reduction of microphotometer tracings of high dispersion spectra of the shell star Pleione. The plate material for the study was obtained by the late Dr Adams of the Mt Wilson and Palomar Observatories and the material reduced so far were taken in the years 1943, 1945 and 1946. Some progress has also been made in the analysis of the atmosphere of the cepheid variable RT Aurigae. It is expected that this study will be completed during 1959.

Photoelectric photometry. (*a*) *Short period variables.*—Gamma Pegasi was observed on eleven nights through both *B* and *V* filters. The observations

obtained are sufficient for an improved study of the period and amplitudes of both light and colour curves. Another Beta Canis Majoris star studied was Delta Ceti. Measures were made on seven nights. The dwarf cepheid CY Aquarii was observed on nine nights to give an improved value of the period and also for studies of the light and colour variations.

Using narrow pass band filters centred on 4050 A and 6100 A, separated by a base line of over 2000 A, light and colour curves were obtained for the Delta Scuti variables Rho Puppis and Delta Delphini. The 4050 A light curve of Rho Puppis has an amplitude of 0·16 magnitude. A change in colour temperature of 300°K is indicated by these measures over a wide base line. Similarly Delta Delphini has an amplitude of colour curve of 0·05 magnitude signifying a colour temperature variation of about 200°K.

(*b*) *Eclipsing variables.*—Observations through interference filters were carried out on eight nights of the Wolf-Rayet eclipsing binary HD 214419. The filters used have half widths of 50 A with peak transmission of 70 per cent and are chosen to isolate the He II lines at 5411 A and 4861 A as well as the continuum at 5000 A and 5300 A. The 4861 A light curve differs slightly from the 5411 A curve mainly because of the changing line contour particularly after both primary and secondary minima.

Several minima of the eclipsing variable Beta Aurigae were observed through *B*, *V* filters. Further observations outside eclipses are needed before an analysis of the light curve can be started. Another eclipsing variable observed through *B*, *V* filters is 29 Canis Majoris.

A programme has been started for the determination of near monochromatic light curves of selected eclipsing variables using interference filters having half widths varying between 40 A and 80 A. Observations made of AR Cassiopeiae in accordance with this scheme had filters centred at 4200 A, 5000 A and 5900 A. This programme will enable the derivation of correct limb darkening coefficients, at these wavelengths, for stars where the eclipses will facilitate such a derivation.

Observations were continued during the year of the two F supergiants 6 Cassiopeiae and Phi Cassiopeiae. 6 Cassiopeiae was discovered to be a variable having a period of about sixty days and an amplitude in the blue of 0·1 mag. Observations are in progress for the determination through a cycle of the light and colour curve. A few runs made of Phi Cassiopeiae did not indicate any light variation greater than 0·01 mag.

(*c*) *Magnitudes and colours.*—Zero point determinations and a few check measures were made on stars in the galactic cluster in Coma Berenices. The observations on these are now complete. Observations of several stars in the cluster Messier 7 were also made during the year. *B*, *V* magnitudes and colours of 72 stars have been measured in the Alpha Persei moving cluster. Reductions of these observations are in progress.

(*d*) *Hγ photometry.*—With the aid of interference filters having half widths of 40 A and centred at wavelengths 4270 A, 4340 A and 4390 A, measures of the Hγ absorption line intensity in early type stars are in progress. The gamma-indices thus obtained are correlated with absolute magnitudes of selected stars in the manner demonstrated by Petrie. Calibrations for the gamma index-luminosity relationship will be obtained from the double cluster in Perseus, the Alpha Persei cluster, the Zeta Persei association, the Pleiades, the Orion association

and NGC 2264. The observations carried out so far indicate that the gamma index can be derived with an accuracy of ±0·005 magnitude facilitating the derivation of a luminosity with a precision better than 0·2 magnitude. The observations made to date cover about a hundred stars. These contain field stars with definite MK spectral classifications, some of Petrie's Hγ stars as well as selected stars with absolute magnitudes brighter than +2·0 in the galactic clusters h and χ Persei, Alpha Persei and the Pleiades.

Positional astronomy.—A Markowitz Dual Rate Moon Camera was received on loan from the U.S. Naval Observatory and was functioning in conjunction with the 10-inch refractor until September 1958. An acute shortage of photographic plates prevented its operation for the rest of the year.

Quartz clocks II and IV ran uninterrupted for most of the year.

The Observatory has a co-operative arrangement with the Smithsonian Astrophysical Observatory, Cambridge, Massachusetts for the optical tracking of Artificial Satellites. A 20-inch *f*/1 Baker-Nunn satellite tracking camera, with associated time standard, was received in April. The camera was put into operation on Manora Peak in August, and satellites have been tracked regularly since September. Both the projects of Moon photography and optical tracking of satellites formed the Observatory's contribution to the programmes of the I.G.Y. These projects are supported in part by a grant from the Council of Scientific and Industrial Research.

Airglow and zodiacal light.—The diurnal variation characteristics of the airglow forbidden oxygen emission lines were studied on several nights during the year. Several maxima of 5577 A were observed in the neighbourhood of midnight. Some of these measures were carried out at times of enhanced solar activity and on such nights large increases in the intensity of 5577 A relative to the continuum at 5300 A were observed.

Towards the end of the year a programme was started for measuring the polarization of the zodiacal light. Preliminary results obtained thus far indicate the feasibility of the technique used.

Instrumental development.—A nebular spectrograph is on order with Messrs Cox, Hargreaves and Thomson Ltd., and is expected to be delivered in 1959. The spectrograph will have a 2-inch aperture *f*/4 collimator and an *f*/0·8 Schmidt camera with field flattener. Three interchangeable gratings will be provided to yield different dispersions. Other items on order with the same firm include the optics of a 10-inch aperture skew-Cassegrain system capable of yielding a 5·5 inch diameter image of the Sun, a 12-inch spherical mirror for an Ebert type photoelectric recording spectrometer, a 6-inch lens for a 25-foot Littrow spectrograph and two 10-inch aperture optical flats. The optics of a Littrow medium dispersion spectrograph have arrived as well as the grating for the high dispersion solar spectrograph. Other gratings have been received for the monochromators to be used for stellar photometry and also for the nebular spectrograph.

An order has been placed with Messrs J. W. Fecker for a 15-inch aperture aluminized reflector to be used exclusively for photoelectric photometry. Delivery is expected soon of an Eichner astrophotometer on the basis of orders placed during the year under review.

There have been several additions to the electronics laboratory and machine shop.

A 6-inch Clark refractor has been received on loan from the American Association of Variable Star Observers. A new mounting complete with synchronous drive is currently being fabricated before the instrument can be brought into commission for photoelectric photometry of the bright variables.

Buildings and roads.—Progress in construction work on Manora Peak continues at a fair pace. The building for housing the 20-inch Schmidt satellite tracking camera together with an attached laboratory and power station were completed by July. A reservoir for water supply to the various buildings on the Peak and electrification of the buildings were completed during the year. Progress of work on the Administrative Block has been slow. Masonry work on a 25-ft diameter dome and associated laboratory has been completed. This building awaits a steel dome which will be delivered in 1959.

Staff.—Messrs N. B. Sanwal and Subhash Chandra were appointed Astronomical Assistants. Mr C. D. Kandpal was appointed Senior Scientific Assistant at the Observatory on a Council of Scientific and Industrial Research scheme. Messrs A. Bhatnagar and S. C. Joshi were appointed Research Assistants and Mr K. K. Srivastava as Project Assistant on the Satellite Tracking Project.

Visitors.—Visiting scientists have included Dr Fred L. Whipple (Smithsonian Astrophysical Observatory) and Drs William Buscombe, Bart J. Bok and Priscilla F. Bok (Mt Stromlo Observatory). Mr Samuel B. Whidden (Smithsonian Astrophysical Observatory) acted as technical advisor on the Satellite Tracking Project during most of the year.

Mount Stromlo Observatory of the Australian National University

(*Director, Professor Bart J. Bok*)

1. *Staff and Visitors.*—There have been no major changes in staff during 1958. We regret to announce that, for reasons of health, Dr G. Hagemann has resigned as of 1958 December 31. Mr J. D. Balfe, Lecturer in Physics at the Royal Military College at Duntroon, is seconded for a two-year period to act as a Scientific Officer in the Time Service.

Dr B. E. Westerlund continued in residence as the Uppsala observer. In recognition of his valuable contributions to Mt Stromlo Observatory, he was appointed an Honorary Fellow in the Australian National University (A.N.U.), Mr C. Jackson continued in residence as the Yale-Columbia observer.

Professor F. B. Wood of the University of Pennsylvania completed his year's work at the Observatory under a Fulbright Award, and returned to the United States. Dr W. G. Tifft, of the California Institute of Technology, arrived in August, with a Fellowship of the U.S. National Science Foundation; he has been named a Visiting Research Fellow in the A.N.U. Dr H. M. Johnson arrived in September. He is employed by the A.N.U. under a contract with the U.S. Office of Naval Research as a Visiting Fellow. Professor Dirk Brouwer and Jan Schilt, and Drs D. W. Dewhirst and T. K. Menon made brief visits to the Observatory.

2. *Instrumental developments.*—The 74-inch reflector has been in uninterrupted use during the year. The astigmatism in the primary mirror has not yet been removed. It is intended to ship the mirror to Grubb Parsons in Great Britain for refiguring as soon as a temporary replacement mirror can be provided. The

mirror was aluminized in the past year (Dr A. R. Hogg and Dr H. R. F. Gollnow). The right wing of the observing carriage has been modified.

The extensive mechanical and electrical work on the 50-inch Melbourne reflector has been completed. The telescope is at present fitted with an *f*/2 spherical mirror and Gregorian secondary, and it is being used quite successfully for photoelectric research. The mirror system provides too small a field of good definition, and therefore is not satisfactory for work on faint stars, or for photographic research. We have now on order from Grubb Parsons a paraboloid 50-inch, *f*/4 primary, with a secondary mirror, to provide an *f*/18 Cassegrain arrangement. We intend to fit this combination with a Meinel Field Corrector.

During 1958 a number of improvements were made on the 8-inch, *f*/1 Schmidt camera and the instrument is now fitted with a variety of colour filters, all of them precision ground and polished, and fitted over the objective lens.

The focusing device on the 20–26-inch Uppsala Schimdt telescope was overhauled and improved; arrangements were also made for the fitting of an objective grating over the correcting plate.

The Stromlo Photographic Zenith Tube, constructed by Grubb Parsons, did not at first operate without difficulties. After considerable mechanical and electrical work, the instrument is now in a satisfactory working condition. The 3-inch transit instrument continues to be in full-time operation. The moon camera on the 9-inch Oddie refractor requires further experimentation.

During 1958 full-scale work was begun on the coudé spectrograph for the 74-inch reflector. Plans for modifications to the pier of the 74-inch building have now been completed and accepted, and construction is in progress. The new coudé housing will protrude northwards from the 74-inch building; the inside dimensions will be, width (east–west) 12 ft, length (north–south) 33 ft and height 29 ft.

To take advantage of the availability of gratings with ruled areas much larger than those previously available, provisions are being made for a collimated beam 14 inches in diameter. Two identical replica gratings, each with 600 grooves per mm and ruled on an area of 6 inches by 8 inches, have been ordered from Bausch and Lomb; these are blazed to yield bright spectra in the second order blue violet. In the end we hope to provide for a four-grating mosaic, measuring 12 inches by 16 inches. The coudé spectrograph will be used initially with two cameras, one with a focal length of 120 inches, the other with a focal length of 8 inches.

Dr Gollnow reports that the tests with the Zeiss-Newtonian spectrograph for the 74-inch reflector have been completed and that the spectrograph is suitable for precision radial velocity work. Temperature control is provided, and the adjustment of the spectrograph for the various prism combinations and temperatures has been completed by Dr Gollnow and Dr A. Przybylski. The instrument is now in full scale operation. It provides notably high quality spectra for luminosity classifications, but is slow by modern standards. Plans are under way for a new fast spectrograph, probably to be used at the Newtonian focus of the 74-inch reflector. A very bright grating, ruled with 400 grooves per mm on a 4 inch × 4 inch area, is being obtained for this purpose from Bausch and Lomb.

Early in 1959 delivery is expected of a new collimator and camera objective for the Cassegrain spectrograph on the 30-inch Reynolds reflector. These are being made at the Defence Standards Laboratory in Melbourne under the

direction of Mr J. A. McDonald and Mr Th. Feuerriegel. A zero power coma corrector has been put into operation on the Reynolds, where it increases the diameter of the usable photometric field for photography from a quarter of a degree to about a degree (Dr S. C. B. Gascoigne and Dr Tifft).

One additional photometer head has been constructed and one of the existing heads is being modified to permit off-set photometry. Through Mr C. Campbell's researches, we are becoming active in the field of infra-red photometry. A new amplifier is in operation on the 74-inch reflector. Dr Tifft brought with him a new refrigeration unit and amplifier; comparative tests have been made between various commercial amplifiers. The amplifier on loan from the University of Pennsylvania, with a built-in integrating unit, is being improved and slightly modified, and the construction of a completely new integrating unit is under way. Interference filters are being installed to permit our entry into the field of narrow-band photometry (Dr Gascoigne and Mr Campbell).

A blink comparator, constructed by Grubb Parsons, was delivered and is in use. The Hilger microphotometer has been modified and made more effective through the installation of a new gear box, supplied by the makers as a replacement for the original fitting. The measuring engine for the PZT photographs is performing well. Dr Gollnow completed his experiments preliminary to the design of a photoelectric setting device, which aims at efficient and accurate measurement of radial velocities, particularly for early type stars, from small dispersion spectra.

3. *Buildings.*—The most important event of the year was the completion of the new electronic, optical and photographic workshop. Within budgetary limitations, every effort is being made to equip and furnish the new workshop adequately.

4. *Student activities.*—1958 will be remembered as the year in which the Graduate School in Astronomy at the A.N.U. came actively into being. At the end of the year we have three Scholars in residence and a fourth is being appointed. We aim eventually to have six scholars from Australian universities, and possibly one or two from abroad. Since there is little undergraduate training in astronomy at the major State Universities, we accept at present students with an adequate background in physics and mathematics, but without previous astronomical training. To overcome this lack of undergraduate training in astronomy, we have undertaken a two year programme of seminars, which serve as an introduction to some of the major areas of modern astronomical research. Mr A. W. Rodgers has been awarded a Ph.D. degree.

In 1957 a programme of Summer Vacation Scholarships was initiated. In the summer of 1957–58 we had seven Summer Vacation Scholars, and this year we have eight.

5. *The site testing programme.*—The available statistics for the twelve months of 1958 show that observations were made on 173 nights, and that clouds prevented observations on 186 nights. On many nights the observations were interrupted or stopped by clouds, and, all told, astronomical work was done during the twelve-month period for a total of 1217 hours. About two-thirds of this time was suitable for photoelectric work. The Observatory obviously needs a Field Station with better conditions for night work than at Mt Stromlo.

In last year's annual report, reference was made to the Yale-Columbia Site Testing Survey, and it was suggested that we wished to see the Stromlo Survey

carried on in close collaboration with that of the Yale-Columbia group. This has not proved practicable, and we are limiting ourselves at present to an exchange of information and reports; our survey is aimed solely at locating a good site for a Field Station for our Observatory.

The following factors, listed roughly in order of priority, have been considered in our search for potential sites for a Field Station:

1. The site should have at least 50 per cent more, and preferably twice as much, clear sky at night as Mt Stromlo Observatory. The sky conditions should be especially favourable from September to March, the season for observation of the Magellanic Clouds.

2. The site should be as far south as possible, preferably below latitude 30° S.

3. Preference is to be given to a relatively isolated hilltop or mountain range, not less than 800 feet above the surrounding plain.

4. Freedom from dust and bushfire smoke is an important factor.

5. The site should not be too isolated, if possible within 30 to 40 miles of a fair-sized town.

6. Sites within relatively easy driving distance of Canberra (6 to 10 hours) are to be given preference over more remote sites. A site within New South Wales would be desirable, to permit close future collaboration with Sydney University and the Radiophysics Laboratory of the CSIRO.

The above considerations have led us to concentrate our efforts during the past year principally on sites in New South Wales and Victoria, but sites in South Australia (Flinders Range) or Western Australia (to the north and east of Perth) will be considered if it can be shown that the New South Wales and Victorian sites are inferior.

The sites were chosen by parties of Mt Stromlo staff, with the aid and guidance of Mr Harley Wood, the N.S.W. Government Astronomer. Local residents have collected meteorological data, including estimates of cloud cover, vertical visibility, stellar scintillation and wind force. A parallel set of observations from Mt Stromlo is being used for monitoring purposes. The data are summarized below:

Site	Altitude in feet above sea level	Altitude in feet above surroundings	Access	A	AA per cent	AAA per cent	Total nights
Mt Ural, Lake Cargelligo, N.S.W.	1810	1000	fair	37	37	28	226
Mt Boona, near Condoblin, N.S.W.	1520	800	easy	48	47	20	204
Kadina Trig, near Alectown, N.S.W.	2391	1000	reasonable	39	<39	<39	180
Mt Bingar, near Griffith, N.S.W.	1494	800	reasonable	54	49	46	207
Mt Arapiles, near Natimuk, Victoria	1176	750	good	58	53	36	63
Mt Stromlo	2560	700	—	28	23	20	226

("A" denotes cloudless nights; "AA" those without cloud or haze; "AAA" those without cloud, haze or marked scintillation. The final column shows the number of nights observed.)

In the course of 1959 we hope to decide on two or three sites to be tested in earnest. Our present plan is to establish at selected spots temporary observatory

camps, with mobile testing equipment. For a month or longer we would plan to conduct at each site minor astronomical research projects, involving the use of photographic and photoelectric techniques, together with visual observations. For the time being it is not our intention to move major equipment from Mt Stromlo to the field station, but we would hope to find the funds to erect a 36 or 40-inch reflector as a new first piece of equipment at the site.

6. *Progress in research.—Dr Hogg* has made a definitive reduction of his photoelectric measurements of magnitudes and colours of 244 bright stars, all based on the *UBV* system. Practically all stars have been compared at least three times with the Johnson-Morgan standards. The list has been reproduced in mimeographed form. Dr Hogg is continuing his photometric studies of galactic star clusters by photoelectric and photographic means. The clusters for which the results are almost complete are NGC 330, 3228, 4755 and 5281. He is preparing an atlas of southern galactic clusters, to include photographs (in blue) with the 74-inch reflector of all clusters south of declination −50°. Two eclipsing binaries (Delta Capricorni and RW Doradus) are being observed photoelectrically with the 50-inch reflector in three colours.

Dr Gascoigne is continuing his researches of the Magellanic Clouds. He has rounded off his photoelectric observations of cepheids, and the results are now being prepared for publication. A preliminary account of this work was presented at the Joint Discussion on the Luminosity of Cepheids, held during the meeting of the International Astronomical Union in Moscow. Observations of fainter cepheids will be continued by photography, primarily at the Newtonian focus of the 30-inch reflector. Much preliminary work has been done on the Mt Stromlo-Uppsala Atlas of the Magellanic Clouds. The wide field photometer has been used throughout the year for the photometry of globular clusters, and results are now available for about 20 clusters. The search for variables in southern globular clusters is continuing by photography. Dr Gascoigne has obtained a set of interference filters, selected for work in Narrow-Band photometry, using Strömgren's *g* and *n* and H-beta criteria of spectral classification. The technique will be applied to measurement of stars, globular clusters and emission nebulae.

Dr T. Dunham, Jnr. has been extremely busy with work on the coudé spectrograph for the 74-inch reflector. He is, in addition, the Observatory's principal adviser on optical problems. In preparation for his researches with the coudé spectrograph, he has made a general study of the distribution of interstellar calcium and sodium in our Galaxy, and work is continuing on an extensive card catalogue of southern stars (all stars to $7^{m}{\cdot}0$; O and B and A stars to $10^{m}{\cdot}0$).

Professor Bok, Mrs J. M. Basinski and Mr K. Gottlieb have completed a survey of optical features possibly related to discrete radio sources discovered by Mr B. Y. Mills at the Radiophysics Laboratory of the C.S.I.R.O. in Sydney. A report on this work was presented at the International Symposium on Radio Astronomy held in Paris in 1958. The programme of photoelectric photometry begun last year as a joint undertaking by Bok and *Dr Priscilla F. Bok* is being rounded off and brought to a conclusion. It concerns standard photoelectric sequencies for Selected Areas 141, 158 and 193, and a check on van Wijk's sequence in the Large Magellanic Cloud. Measures of colours and magnitudes for O, B and A stars, and for certain cepheid variables are under way for the

Large Magellanic Cloud and for the Carina-Centaurus region. Supplementary photographic studies, mostly from Uppsala Schmidt plates, are being carried out in collaboration with Mrs Basinski.

Dr Gollnow, Dr Przybylski, and Dr Hagemann, continue their long range programme of radial velocities for the Scorpio–Centaurus cluster and for stars in the FK3 and N30 catalogues. Jointly with Dr Przybylski and Mr J. B. Whiteoak, Dr Gollnow is engaged upon a spectroscopic and photoelectric study of the Theta Carinae cluster.

Dr Przybylski is working on a programme of spectral classification and photoelectric observations of 170 southern high velocity stars, and he is also giving attention to photometry and spectroscopic studies of Nova Ophiuchi, 1957, and Nova RS Ophiuchi. He is rounding off his theoretical researches on model stellar atmospheres and he continues his work on artificial satellites.

Dr Hagemann's major effort was in connection with radial velocity measurements from plates made with the 30-inch Reynolds reflector. He has computed a spectroscopic orbit of Zeta Phoenicis; absolute values for the components were derived from a comparison with Dr Hogg's photometric elements.

Dr W. Buscombe has completed and published his finding list of southern stars of high velocity, a joint project with *Miss P. M. Morris*. He and Miss Morris coordinate the activities in the field of spectral classification with the Zeiss–Newtonian spectrograph, and they are making special efforts to see that the system of classification parallels closely that of W. W. Morgan and associates. During his study leave, Dr Buscombe visited most of the major observatories engaged on research in spectral classification. At the Moscow meeting of the I.A.U., he presented to Commission 30 a list of 75 radial velocities determined from measurements made on plates taken with the Cassegrain spectrograph on the 30-inch Reynolds reflector. Dr Buscombe and Miss Morris are stressing in their radial velocity work the region of the Scorpio–Centaurus cluster and stars in the FK3 and N30 catalogues. Dr Buscombe has completed an analysis of velocity residuals for the Cassegrain programme and he has also prepared a review article on subdwarf stars.

Dr Rodgers has completed a research on three-colour photometry in the Southern Coalsack. He has been principally active as an observer with the 8-inch Schmidt camera and with the Zeiss-Newtonian spectrograph on the 74-inch reflector. Good progress is reported on an H-alpha and comparison band survey with suitable colour filters of the southern Milky Way. The Schmidt programme has so far led to the detection and listing of 100 new H II regions. The 8-inch Schmidt is also being used for surveys of known southern dwarf galaxies and for studies of the Magellanic Clouds. Uppsala Schmidt photographs have been searched for possibly exciting stars of H II regions in the Milky Way between galactic longitudes 275° and 310°; 480 early OB stars with $m < 12{\cdot}5$ have been detected and listed. Spectra of 70 OB stars were photographed with the Zeiss-Newtonian spectrograph, and slit spectra were also obtained for three globular clusters in the Galaxy and five globular clusters in the Small Magellanic Cloud. Work continues on an H-alpha atlas of the southern Milky Way.

The Uppsala observer, *Dr Westerlund*, continues to work in close collaboration with the Mt Stromlo staff members. We exchange telescope time with

him whenever he wishes to use one of our instruments, and this has enabled the Observatory staff to make effective use of the Uppsala telescope. Dr Westerlund's presence at Mt Stromlo is very much appreciated by staff and students. His helpful participation in our colloquia and group discussions and his advice with regard to observing programmes and their execution are proving a great help in our scientific work.

Dr Westerlund has kindly given us permission to list briefly some of the researches on which he is engaged. He is stressing photometry and spectral classification in the infra-red and red regions. The Magellanic Clouds, the globular cluster 47 Tucanae, the region of the Southern Coalsack (research completed), a region in Carina, and a complex region at the junction of Norma and Scorpius are being investigated by these techniques. Supplementary H-alpha surveys are being carried out. The 30-inch Reynolds reflector and the 20-inch Catts reflector have been used by Dr Westerlund for photoelectric observations in the *UBV* of relatively bright A stars within 15° of the South Galactic Pole; bright blue supergiants; bright M stars classified at Mt Wilson; and selected red stars from the Schmidt surveys. Work on two photoelectric magnitude sequences is also well advanced (to $m = 14$).

Dr Wood completed his intensive studies of light curves of southern eclipsing variables. *Dr Tifft* is initially concentrating his efforts on photographic and photoelectric studies of colour magnitude arrays for several globular clusters in the Magellanic Clouds, and he is working on a combined photographic and photoelectric survey of cepheids in one section of the Large Magellanic Cloud, a programme that will probably be extended. *Dr Johnson* is working with the 8-inch Schmidt camera and with the Zeiss-Newtonian spectrograph on the 74-inch reflector. He is especially interested in problems related to the nucleus of our Galaxy, and an infra-red study is planned for this part of the sky and also for the Large Magellanic Cloud. His principal programme will be a photographic study of photometry in H-alpha, in a comparison pass band, and in H-beta of several sections of the southern Milky Way. The aim of this survey will be to prepare isophotal charts for the radiation in the two Balmer lines, correcting for interstellar extinction, for H II regions of the southern Milky Way. A special study is being planned of the radio source Centaurus A (NGC5128). 74-inch spectroscopic observations will be used throughout to supplement the data obtained with the 8-inch Schmidt camera.

The three scholars are firmly embarked on their thesis projects. *Mr R. A. Bell* has begun a spectroscopic survey of southern white dwarfs. Identification charts have been prepared with the Uppsala Schmidt and the first group of spectra has been obtained with the Zeiss-Newtonian spectrograph on the 74-inch reflector. To supplement this work, photoelectric colours and magnitudes are being determined with the 30-inch Reynolds reflector. *Mr Campbell* participated in the H-alpha survey of the Southern Milky Way. He took part in the search for new H II regions, applying the technique of the Blink Microscope. His major project is, however, infra-red photoelectric photometry. The receiver is an infra-red photomultiplier tube, made available to Dr Hogg by Professor Lallemand of Paris. He is combining three approaches to the infra-red classification of the spectra of late type stars. On the advice of Dr Gascoigne and Dr Westerlund, Mr Campbell has selected eleven interference filters of suitable band width, so located that they isolate the principal spectral features, and give a

measure as well as the height of the continuum in the neighbourhood of these features. The second approach is with the aid of a spectrum scanner, and again photoelectric recording. Wide-band photometry is also planned for the same stars, which will permit the derivation of *R* and *I* colours in addition to the usual *UBV* colours. In addition to participating in the study of certain southern OB associations and the associated emission nebulosity, *Mr Whiteoak* has taken part in the southern Milky Way survey with the 8-inch Schmidt. The two associations on which he is now concentrating are located in the Milky Way near R. A. 16^h. The areas to be studied are delineated from objective prism plates taken by Dr Rodgers with the Uppsala Schmidt telescope, on the basis of spectra being classified by him. The brighter stars are being observed with the Zeiss-Newtonian spectrograph on the 74-inch reflector, and magnitudes and colours are obtained photoelectrically with the 20-inch Catts reflector. To supplement the classification from slit spectra, Mr. Whiteoak is applying the narrow-band filter technique to the region of H-beta.

7. *The National Time Service.*—The National Time Service has continued to make astronomical time determinations and to provide the time signals for transmission by Belconnen Naval Wireless Station; to measure and report on time signals received by radio, and on clock signals received by land line from the National Standards Laboratory, Sydney, the Postmaster General's Research Laboratories, Melbourne, and the Adelaide Post Office. Innovations have been deferred until the return of Mr H. J. McK. Abraham, who is visiting related institutions in the United Kingdom, Europe, the USSR, the USA and Canada.

Transit instrument.—The time determinations are made with the transit instrument. Normal evening observations are supplemented for the I.G.Y. programme by an equal number after midnight.

Photographic Zenith Tube.—An examination of extra-focal images indicated that there was a fault in the adjustment of the components of the objective. This has been corrected, thanks to the National Standards Laboratory, where it was shown that wear on the lens seatings during delivery had created a problem. In addition, much effort has been devoted to finding eliminating sources of mechanical and electrical faults. This work was done by *Mr and Mrs H. Wehner* and *Mr D. G. Thomas.*

The star list is being made more comprehensive so that the apparent places of stars for both present and future use can be calculated together for several years in advance. Mrs Wehner is in charge of the routine PZT photography and measurements.

The Moon Camera has been fitted on the Oddie 9-inch refractor. Checks were made on the interval between the times of the contacts and the time at which the moon filter is parallel to the photographic plate. Plates which have been obtained during timed observations are being examined. *Mr Balfe* is in charge of the work.

Melbourne Catalogue of Fundamental Stars.—A generous offer from Pulkovo Observatory and the Academy of Sciences of the USSR to reduce and publish this catalogue has been accepted.

Computing developments.—Mr J. M. Boots and *Mr J. I. Grenot* are taking a special interest in the application of modern computing techniques to the problems of the Time Service. The processing of the data collected by the Time Service is greatly in need of modernization. Since new computing

facilities are becoming increasingly available in Australia, it should be possible to carry out reductions by modern machine techniques fairly soon.

8. *Travel and Scientific Meetings.*—Professor Bok, Mr Abraham, Dr Buscombe and Mr Gottlieb attended the Tenth Congress of the International Astronomical Union in Moscow. Bok visited the United States for six weeks prior to the Moscow meeting, and attended the International Symposium on Radio Astronomy in Paris in August. He visited the Uttar Pradesh State Observatory at Naini Tal in India. Mr Abraham visited observatories and Time Services in the United Kingdom and Western Europe prior to the Moscow meeting. He was a member of the Australian Delegation to the meeting of the I.G.Y. in Moscow. He is now spending six months at the Dominion Observatory in Ottawa, Canada, and will return to Australia via the United States. Dr Buscombe also visited the Uttar Pradesh State Observatory, and observatories in Western Europe. He has spent three months at the University of Toronto and the David Dunlap Observatory. Mr Gottlieb visited Western Europe and United Kingdom observatories before attending the Radio Astronomy Symposium in Paris and the meetings of the I.A.U. in Moscow. He spent three months in the United States, a visit made possible by a Carnegie Corporation Travel Grant. Dr Buscombe and Mr Gottlieb attended the symposium on Image Converters, held at the Imperial College, Kensington.

Dr Hogg, Dr Dunham and Dr Gollnow, with Dr Westerlund, attended the meeting of the Australian and New Zealand Association for the Advancement of Science, held in Adelaide in August 1958. All of them presented papers at the Symposium on " The Measurement of Astronomical Distances and the Scale of the Universe ", which was organised by Dr Hogg.

During 1958 we continued to have close working relations with the Radiophysics Laboratory of the C.S.I.R.O. in Sydney. Five colloquium talks were given at Mt Stromlo by members of the Radiophysics Laboratory, and two Radiophysics staff members, Dr C. S. Gum and Dr C. M. Wade, made visits of two weeks to Mt Stromlo, participating in the Observatory programmes. In November, 1958, a joint symposium was held at Mt Stromlo on " Observational Problems of H II Regions ".

9. *Lectures and public relations.*—The Observatory continues the policy of being open to visitors at set time during the day and on certain special nights. On Saturdays, Sundays and holidays, there is a regular afternoon showing. Mr Wehner is in charge of the Wednesday evening visits. In addition, we have again had eight monthly Visitors' Nights, each with an average attendance of 125 to 150 persons. The number of daytime visitors approached 6,000, and approximately 1,700 have visited the Observatory at night.

Riverview College Observatory, N.S.W.

(*Director, A. Fynn, S. J.*)

During 1958 the astronomical work was considerably curtailed owing to the long illness of the late Director, Father T. N. Burke-Gaffney. Unfavourable weather conditions further hampered observational work. In all, only 232 photographs of star regions were obtained. Observation of occultations suffered as a result of bad weather and depleted staff. Only one occultation was observed.

Astronomical and geophysical information was supplied to public bodies and private enquirers. The library was used extensively by persons and institutions to whom astronomical literature is not otherwise easily available.

Father Burke-Gaffney died on 1958 September 14. He had been Director since 1952. His successor, Father Anthony Fynn, S.J., will take up his post in January, 1959.

Sydney Observatory

(*Director, Harley Wood, Government Astronomer*)

The work on the Astrographic Catalogue has been continued. Volumes 39, 40 and 41 have been printed and distributed and Volumes 42 and 44 are now in the hands of the printer. Volume 6 of the Melbourne section of the Astrographic Catalogue was printed in Paris under the direction of Dr J. Baillaud and has been distributed. He is now supervising the publication of Volume 7. The work on Volume 8 is proceeding at Sydney Observatory.

The programme of observation of occultations predicted in the Nautical Almanac has been continued, as also has the photographic observation of double stars.

We continued to observe minor planets which culminate south of the equator. Apart from the general observations, sets of observations are made on the minor planets which have been selected for purposes of fundamental astronomy. The observations of this kind made during 1955 and 1956 have been published and during 1958 a set of observations were made on the minor planet, Parthenope.

Assistance has been given to Dr I. Epstein and Professors D. Brouwer and J. Schilt, who visited Australia to look for a site for their proposed 20-inch astrograph.

This year we celebrated the centenary of the entry into residence on 1858 April 11, in the present building of William Scott, the first Astronomer of Sydney Observatory. A commemorative function was held on 1958 April 11, and a History of the Observatory is being issued as Sydney Observatory Papers No. 31.

The civil and educational work of the Observatory has been continued as in previous years.

Radiophysics Laboratory, Sydney

(*Chief, Dr E. G. Bowen*)

The radio astronomy group is under the direction of Dr J. L. Pawsey.

During 1958, observations were made which give important evidence on the mode of origin of a number of different types of solar radio emission. The 20-cm radio heliograph gave information on brightness temperature and polarization which leaves little room for doubt that the " slowly varying component " is due to simple thermal emission from extra dense regions in the lower corona. Following this demonstration, observations of the characteristic bright regions, " radio plages ", over a range of wavelengths are now being used to determine details of structure in the lower corona. Incidentally, these regions appear to

be the source of a major part of the radiation, ultra-violet or X-ray, which generates the terrestrial ionosphere.

At metre wavelengths, observations of spectra and apparent positions of bursts have consolidated the hypothesis that certain types of bursts (Types II and III) are due to plasma oscillations excited by travelling disturbances in the higher solar corona. Observations of another type of bursts (Type IV) support the French suggestion that the latter are due to the synchrotron emission mechanism and hence may well be associated with the emission of cosmic rays by the Sun.

An important development in the galactic field is the recognition, from observations using the 85 Mc/s Mills Cross, of spiral structure in the galactic continuum emission from the disk. The 21-cm hydrogen line studies of the disk provided a substantial fraction of the evidence on which the I.A.U. are basing the new system of galactic coordinates.

On the equipment side, work is proceeding on the detailed design and placing of contracts for the construction of the giant 210-ft diameter radio telescope which is shortly to be installed near Parkes, about 200 miles from Sydney. A 60-ft paraboloid is being erected near Sydney.

1. *Cosmic radio waves*

Continuous emission.—The reduction of observations made with the 85 Mc/s Cross during the last four years is almost completed. A catalogue of radio sources in the declination range $+10°$ to $-20°$ has been published (**17**) and catalogues for the remainder of the southern sky are in preparation. Detailed contour diagrams have been published of radio brightness of a strip 10° wide along the Southern Milky Way (**8, 16**), of various strong discrete sources resolved by the instrument (**33**), of some interesting regions of excess emission in the constellations of Vela and Puppis (**26**), and of the region of the " Local Supergalaxy " (**7**). It has been found that radiation previously attributed to the southern part of the " Local Supergalaxy " is more likely to be of galactic origin. A diagram showing the main features of the distribution over the visible sky has been prepared by averaging sets of records and has been used to examine the spatial distribution of the emission from the galactic corona (**14**).

Analysis of the " disk " component of the galactic radiation has led to very interesting results (**14**). It has been found that, where the spiral structure is well defined, this component is confined to the spiral arms, and it has been possible to trace broadly the radio spiral pattern to within about 2 kpc of the galactic centre. The spiral pattern so deduced generally agrees will with the results of optical and H-line studies where these are free from scale uncertainties.

Examination of the distribution of radio sources and their possible identifications continues. The statistical properties of the galactic radio sources suggest that the majority are Population I objects and possibly associated with Type II supernova remnants (**13**). An important feature of the sources at high galactic latitudes is the large proportion which have angular sizes of more than about $\frac{1}{2}°$. It is not yet clear whether these are close blends or extended sources, but they appear to be responsible for many of the discordances between surveys using different types of instruments (**13, 17**). A comparison has been made between the published radio source catalogue (**17**) and the Palomar Sky Survey plates. Many new possible identifications have been found with faint galaxies; this work is being prepared for publication.

On the instrumental side, the original 85 Mc/s Cross has been modified to operate as an interferometer using a remote aerial with a radio link. It is used for angular size measurements in the range 10″ to 1′ arc. It has been used initially to check the possible galaxy identifications noted above. Eventually it is intended to observe all the sources in the southern sky within its sensitivity limitations: these should comprise more than one quarter of the catalogued sources.

The collection and analysis of the records obtained around the galactic equator with the 19·7 Mc/s Cross is nearing completion. A preliminary report (**31**) outlined the way in which these observations can give information concerning the distribution in depth of the regions responsible for the disk component of the galactic emission. Observations of the Magellanic Clouds show the H II region 30 Doradus in absorption, and it is possible to use this feature to separate the galactic and extra-galactic contributions to the brightness observed away from the galactic plane (**32**).

A number of discrete sources have been studied and a comparison between the features of the sources Fornax A and Centaurus A has been published (**30**). Centaurus A shows evidence of spiral structure in its extreme outer regions.

Other observations have been made of the continuous emission in the neighbourhood of the 1420 Mc/s spectral line. In one series of observations the 36-ft transit parabola was used to study some bright thermal and non-thermal sources, with the aim of combining the measurements with low-frequency and optical data to explore the physical state of the radio sources. In the other, the aerials of the 64-element crossed grating interferometer, used for solar studies, were connected as interferometer pairs with different spacings to determine the brightness distribution over 8 of the brightest southern sources. Accounts of these observations and their results are being prepared for publication.

Hydrogen line studies.—The survey of the 21-cm line emission from the Southern Milky Way has now been completed and the results submitted for publication. The observations were carried out with an aerial beamwidth of 1°·4, and a bandwidth of 40 Kc/s, along 41 tracks crossing the galactic equator in the longitude range 175°–5° (old system). These results, when combined with those already published by the Leiden group, give a coverage of the whole Milky Way strip at about the same resolution.

A hydrogen spiral structure diagram for the whole Galaxy has been prepared in collaboration with Leiden Observatory (**19**). It is evident, however, that the velocity model which was used in the reduction of the northern observations gives less satisfactory results when applied to the southern data. A revised velocity model is now being derived from a study of the 21-cm profiles, and a new spiral diagram will then be prepared.

The Sydney and Leiden 21-cm data have shown that the central region of the Galaxy, out to a radius of about 7 kpc, is exceedingly flat; a solution has been made for the mean plane of the neutral hydrogen over this region. The new I.A.U. system of galactic coordinates is based primarily on this evidence.

The multi-channel receiver (**12**), which has been under development, has been in operational use during the year. This receiver has 48 channels covering a bandwidth of 1½ Mc/s, and is capable of producing a complete line profile in the very short time of two minutes. This type of equipment is particularly suitable for studying extensive regions.

A region in Taurus and Orion, of approximately 3,500 square degrees, has been studied with a low-resolution aerial (2°·8 beam) (**12**). This study has

demonstrated the potentialities of the instrument in rapidly surveying large parts of the sky. This low-resolution survey will be extended to the greater part of the visible sky before transferring the receiver to the 60-ft aerial which is at present being mounted.

2. *Solar radio waves*

Radio heliograph.—The 20-cm radio heliograph (64-element crossed-grating interferometer), which is used to scan the Sun with a 3′ arc pencil beam, has been in operation for nearly two years. Daily maps showing the distribution of radio brightness over the solar disk are derived. The observations have shown that the bright regions, which we may term " radio plages " and which are the source of the slowly varying component of the solar radiation, have brightness temperatures of about $1{\cdot}5 \times 10^6$ °K (**2**). This result, and the absence of any marked circularity in the polarization of the radio emission at a wavelength of 20-cm, leave little doubt that the emission is thermal, from high density regions in the corona.

With the collaboration of observers in Japan, the U.S.A. and France, a special study of the electron distribution in one of these radio plages is being undertaken. The combined observers have available multi-element grating interferometers of high resolving power at wavelengths of 7·5, 21, 88 and 176 cm. Preliminary results show that the region of excess density extended over a range of heights from 20,000 to more than 300,000 kilometres.

Radio spectrograph and swept-frequency interferometer.—The investigation of bursts of radio emission from the Sun has been intensified during the year. The radio spectrograph which has been in operation since 1952 in the frequency range 40–210 Mc/s has now been extended to 25–210 Mc/s to permit the following of solar corpuscles to much greater heights in the solar corona. The swept-frequency interferometer, built for locating the sources of solar bursts at different frequencies, has been further extended and improved, and facilities for automatic computation of positions have been incorporated.

The first results of the new equipment (**43**) have confirmed the hypothesis that Type II and Type III bursts are due to plasma oscillations in the coronal gas; radiation at different frequencies emerges from different heights in the Sun's atmosphere as predicted on the plasma oscillation hypothesis. The results have also confirmed that the sources of Type III bursts travel outwards with velocities approaching that of light. New evidence has been obtained, both from interferometer observations and from correlations, which strengthens the association between Type II bursts and the passage of geomagnetic particles through the Sun's atmosphere. In contrast to the " plasma " emissions of Types II and III, the emissions of Type IV following large flares have been found to arrive from a common direction which is independent of frequency; this indicates an emitting process other than plasma oscillations, thus supporting the synchrotron hypothesis of French workers.

Occultation of Crab nebula.—In order to obtain information on the solar corona, occultations of the Crab nebula by the Sun were observed using the 85 Mc/s Mills Cross during June 1957 and 1958. When the separation of the radio source and the Sun was less than 8 solar radii, the brightness distribution, as measured both by a narrow fan-beam and by a pencil beam, showed an asymmetry which cannot be explained by simple scattering; at least half the effect must be caused by refraction.

Editing of solar radio emission observations.—Editing work has continued on overseas and local observations on Solar Radio Emission for the Annals of the I.G.Y. and for the Quarterly Bulletin on Solar Activity.

3. *Theoretical*

The theory of the ejection of solar gas from the vicinity of flares has been developed, leading to a model of the interplanetary magnetic field. The mainly radial lines of force may explain some observed cosmic ray variations (**25**). A theory of the transmission of geomagnetic disturbances through the Earth's atmosphere has been developed taking account of the separate motions of the ion plasma and the neutral atom gases. This theory has led to some new ideas about geomagnetic storms, including an explanation of the main phase.

A physical explanation has been given of growing space-charge waves in two interpenetrating ion streams (**23**) which shows that the medium is unstable. The effect is a non-oscillatory exponential growth of ion clouds which may be at rest or drifting with the medium as a whole.

Several problems in radio emission, propagation and absorption have been solved. The theory of radio emission of H II regions with irregular distributions of electron density and temperature has been extended (**39**). Emission at the gyro-frequency and its harmonics has been estimated (**38**), and emission by organized groups of electrons by the Cerenkov, gyro, synchrotron and free-free processes discussed (**36**). Methods of ray tracing in a magneto-ionic medium have been further developed.

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Perth Observatory

(*Director, Mr H. S. Spigl, Government Astronomer*)

The programme of observation with the Markowitz moon position camera attached to the astrographic telescope was commenced in May after completion of tests and adjustments. Faulty plates restricted the amount of work possible near full Moon during the last 4 months of the year, and 46 satisfactory pairs of plates have been obtained.

The results of 24 occultation observations were communicated to H.M. Nautical Almanac Office.

The new Shortt free pendulum clock has been installed and now provides ONOGO signals for shipping, " six pips " hourly signals to radio stations and direct line communication for railway and telegraphs.

The seismograph recordings were analysed, and results distributed, as in previous years.

Routine work includes press and public information services, preparation and publication of tide tables, coordination of observations by the Perth moon-watch team, and afternoon and evening demonstrations for the general public.

Visitors have included Dr D. Carder of U.S. Coast and Geodetic Survey, Professors D. Brouwer of Yale and J. Schilt of Columbia University, Mr C. Jackson of Yale-Columbia Southern Station, Canberra, and Dr D. W. Dewhirst of Cambridge University.

In October the Government Astronomer commenced a year of overseas travel to visit observatories throughout the world.

Geophysical Observatory, Christchurch, N.Z.

(*Superintendent, Dr J. W. Beagley*)

The Observatory is now located on the sixth floor, St. Elmo Courts, Hereford Street, Christchurch. Much improved facilities for carrying out both recording and research programmes are provided in the new accommodation.

Throughout this year continuous vertical soundings of the ionosphere have proceeded at the five stations under the Observatory's control at Godley Head, Christchurch; Rarotonga, Cook Islands; Campbell Island; and Scott Base and Cape Hallett (in conjunction with U.S.A.) in Antarctica. New aerials erected

at Godley Head, double the length of those formerly used, have improved recording at lower frequencies at this station. Continuously recording fluxgate magnetometers have also been operated at ionosonde locations.

A prototype fixed frequency recorder has been developed in the Observatory laboratory and is nearing completion. Constructed for detailed investigation of solar flare effects in the lower ionosphere this instrument has been designed to record peak echo amplitudes from the E region with a time discrimination of one second. Particular attention has been paid to stability and facilities for calibration so that, if aerial constants are known, absolute absorption readings are possible. Preliminary testing has been successful.

The cosmic ray programme in Christchurch consisting of continuous Ion Chamber and Meson telescope recordings has operated satisfactorily and the Invercargill Meson Telescope constructed at the Observatory was installed in February and began reliable continuous operation in March.

Ionospheric and cosmic radiation data has been forwarded currently to I.G.Y. World Data Centres and considerable progress has been made with preparation of data for publication. The annual volumes of ionospheric data 1956 and 1957 (Godley Head, Rarotonga and Campbell Island) have been completed and will be published shortly. The 1957 volume contains full I.G.Y. data from July 1. Work is proceeding on the Scott Base and Cape Hallett publication for the 1957–58 I.G.Y. period.

Research projects during the year include true height analysis of selected calm days at Godley Head during the I.G.Y.; investigation of ionospheric effects at Rarotonga of the Johnston Island missle explosions in August; analysis of Chapman behaviour in the lower E region; anomalous behaviour of the F_1 region; sunspot cycle changes of MUF 3000 and MUF 800 based on Godley Head data.

The eclipse effect of October 12 GMT was well recorded by the ionosonde at Rarotonga which was near the line of totality.

Carter Observatory, Wellington, N.Z.

(*Director, Mr I. L. Thomsen*)

Telescope demonstrations and lectures were given on 40 occasions to the public, and attendances totalled 1,575.

The Observatory has continued to give assistance to amateur societies whenever required and has made the lecture room available for meetings. For instructional purposes, 3-inch refracting telescopes were on loan to four secondary schools in New Zealand.

Regular observations of sunspots by projection with a 5-inch refractor have been continued.

Visual auroral observations have been collected and analysed as in former years. The instrumental side of auroral work both in New Zealand and the Antarctic has become more predominantly the care of the Department of Scientific and Industrial Research.

Short-term ionospheric disturbance forecasts ceased for the Royal New Zealand Navy, but are being continued for the New Zealand Broadcasting Service and the Post and Telegraph Department.

The Markowitz Moon Camera on loan from the U.S. Naval Observatory was successfully adapted to the 9-inch telescope and a number of plates taken. Undue plate darkening however indicates that more work has to be done to obtain plates of the best quality.

The Director, accompanied by Mr R. Dibble of the Seismological Observatory as Government Representative, visited the island of Atafu to observe the total solar eclipse of 1958 October 12. The instrument was the quadruple camera fed by coelostat as used by Dr H. von Klüber in Egypt, and was made available on loan to the New Zealand Expedition by the Joint Permanent Eclipse Committee through the good offices of Professor R. O. Redman, F.R.S. On the island was also the United Kingdom party of Dr H. von Klüber and Dr A. H. Jarrett. Both these gentleman gave helpful advice in the work. Five successful plates were secured, but pressure of work has so far not enabled any study to be made of them.

It is most regrettable to record that the volume of productive work fell during the year due to heavy increases of administrative work and a changing staff. Considerable time was absorbed with I.G.Y. matters both locally and internationally.

There is the possibility that auroral work at the Observatory will end in 1959, and be continued in some form by the Department of Scientific and Industrial Research. This, it is hoped, will leave more time for astronomical work of some kind still to be decided upon.

Many external lectures have been given at the popular level and information supplied to the press as required. General astronomical information has been provided on application to calendar printers, architects, solicitors, the armed forces and Government Departments.

Mr M. Abdul Ahad's Observatory, Basrah, Iraq

During 1958 routine solar observations were continued as weather permitted, particularly in sunspot sketching and the practice of experimental solar photography.

The 6-inch reflector was the main instrument of the Observatory by means of which 32 observations of the Moon and 30 observations of Jupiter and Saturn were made.

This Observatory received many visitors during the year; they were much impressed by the good results obtained from the preliminary instruments used.

Mr J. D. Bestwick's Observatory, Leek, Staffordshire

From January to July many detailed drawings of Jupiter were made with the 12-inch reflector. Drawings of faint details on Venus and Mercury were also obtained. Owing to poor seeing conditions, only six detailed drawings of Mars were made during the opposition.

As before, a study was made of fine lunar clefts and domes, most of the work being confirmatory. All observations were sent to the appropriate Sections of the British Astronomical Association and to the Association of Lunar and Planetary Observers. Many people visited the Observatory during the year.

Dr J. L. Haughton's Observatory, Littleton, Nr Winchester, Hants

Cloudy weather made it impossible to observe more than six occultations this year, and restricted the number of visitors to 26.

A few observations were made of Mars, and one or two astronomical lectures were given.

Mr F. M. Holborn's Observatory, Peaslake, Surrey

During 1958, 1328 observations were made of 71 variable stars and novae on 125 nights. The Sun was observed on 178 days for spot counts and naked-eye spots. All records were communicated to the British Astronomical Association except those of Gamma Cassiopeiae which were sent to the Norman Lockyer Observatory.

Mr Patrick Moore's Observatory, East Grinstead, Sussex

Work with the main instruments, a 12½-inch and an 8½-inch reflector, has followed the same pattern as in previous years. Lunar studies have been continued, particular attention being paid to drawing up a full catalogue of domes; on Jupiter, more than 300 transits of surface features were obtained, and observations of Venus were maintained. Results have been published in the Journal of the British Astronomical Association and elsewhere. There were many visitors to the Observatory during 1958.

Mr G. E. Patston's Observatory, Eastbourne, Sussex

Throughout 1958 work on the programme of irregular variable stars was hampered by paucity of observing nights, although seeing conditions generally were superior to those of 1957.

The writer would welcome contact with another observer of CN Orionis and TZ Persei, in which he is especially interested. Of the latter, no standstill was observed during 1958 and some very bright maxima have been seen.

A Dall ortho-barlow unit has been acquired, giving superb definition and great convenience in rapid changing of powers.

A few visitors were welcomed to the Observatory on moonlit nights.

Dr R. L. Waterfield's Observatory, Ascot

The 6-inch Cooke triplet continued to be used for cometary photography, but owing to the dearth of these objects and bad weather only 12 plates were secured during the year. These included a number of unsuccessful search plates, 4 exposures on comet Burnham, 1958a, and 3 exposures on comet Burnham-Slaughter, 1958e. 3 plates of the former comet and 1 plate of the latter comet were measured and reduced and the positions communicated to the I.A.U. circulars. This instrument was also used for photographing the Russian rockets and various methods were tried out for getting accurate timed positions. Towards the end of the year there was completed a louvre-type shutter fitted with electric contacts in circuit with a chronograph, which was placed in front of the

lens and made interruptions in the photographic trail that could be measured to within about 2 seconds of arc and 1/20th of a second of time. This apparatus was adapted from a 10-inch signalling shutter kindly loaned by the Admiralty.

5 occultations of stars by the Moon were observed with the 6-inch refractor and the times communicated to H.M. Nautical Almanac Office.

Dr H. P. Wilkins's Observatory, Bexleyheath, Kent

The 15¼-inch reflector has been used for lunar and planetary work and for the instruction of the Crayford Manor House Centre Astronomy Class members, on double and variable stars. Observations of Mars were supplemented by others secured with the aid of the 24-inch Cassegrain reflector at the Meudon Observatory.

A reddish patch close to the central peak within the lunar formation Alphonsus was seen on November 19 and again on December 19; apparent confirmation of Kozyrev's announcement of an eruption.

Observations of solar prominences were continued, using a 6 prism spectroscope attached to the 3·6-inch refractor. It is hoped to have the new 22-inch reflector in operation shortly.

The writer has been appointed Director of a new Observatory and Planetarium set up at the Crayford Centre. The Observatory is equipped with a 12-inch equatorial reflector, and a spectrohelioscope, while the Planetarium projector is adapted for a 12 foot diameter dome.

REPORTS ON THE PROGRESS OF ASTRONOMY

DEFINITION OF THE NEW I.A.U. SYSTEM OF GALACTIC COORDINATES

At the Dublin General Assembly of the International Astronomical Union in 1955, Sub-Commission 33b of the Union was appointed " to investigate the desirability of a revision of the galactic pole and of the zero of galactic longitude ". At the Moscow General Assembly in 1958 the conclusions and recommendations of this Sub-Commission were reported and discussed in a joint meeting of Commissions 33 (Structure and Dynamics of the Galaxy), 33b, and 40 (Radio Astronomy). The General Assembly subsequently passed a resolution proposed by Commissions 33 and 40, which among other items, contained the following recommendations :—

> ..... "(*c*) That Commission 33b be authorized to define the exact values of the coordinates of the pole and of the zero of longitude immediately after the final reduction of the relevant observations is finished.
>
> (*d*) That Commission 33b be charged with the communication of these values to the members of the I.A.U. and to all other interested institutions and individuals ".

Commission 33b has now completed the final reduction of the observations referred to in item (*c*), and it has defined the following values of the relevant quantities :—

(1) The new north galactic pole lies in the direction

$$\alpha = 12^{h}49^{m} \quad \delta = +27^{\circ}{\cdot}4 \quad \text{(equinox 1950·0)}.$$

(2) The new zero of longitude is the great semicircle originating at the new north galactic pole at the position angle

$$\theta = 123^{\circ} \text{ with respect to the equatorial pole for 1950·0.}$$

(3) Longitude increases from 0° to 360°. The sense is such that, on the galactic equator, increasing galactic longitude corresponds to increasing right ascension. Latitude increases from −90° through 0° to +90° at the new north galactic pole. The system is therefore similar to the Ohlsson system of coordinates.

The above quantities are to be regarded as exact so that the new galactic coordinates may be computed to any desired accuracy in terms of right ascension and declination for the equinox 1950·0.

Other useful values (restricted accuracy)

The quantities which follow have been computed from the definition but are given only to an accuracy of the nearest integer in the last digit.

(*a*) *The 1900·0 values corresponding to those in the definition*

$$\left.\begin{array}{l}\text{New pole } \alpha = 12^{h}46^{m}{\cdot}6 \\ \qquad\quad \delta = +27^{\circ}40'\end{array}\right\} 1900{\cdot}0$$

New longitude zero at position angle $\theta = 123^{\circ}04'$ (1900·0)

(*b*) *The old galactic coordinates of the new pole*

$$l^{I} = 347^{\circ}{\cdot}7, \quad b^{I} = +88^{\circ}{\cdot}51$$

(*c*) *Position of the point of zero longitude and latitude* (*new system*), $l^{II}=0$, $b^{II}=0$.

In equatorial coordinates

$$\alpha = 17^h39^m{\cdot}3, \quad \delta = -28°54' \quad (1900{\cdot}0)$$
$$\alpha = 17^h42^m{\cdot}4, \quad \delta = -28°55' \quad (1950{\cdot}0)$$

In old galactic coordinates

$$l^I = 327°{\cdot}69, \quad b^I = -1°{\cdot}40$$

Nomenclature.—At the Moscow Assembly it was decided that the symbols l, b should be retained for galactic longitude and latitude respectively. Commission 33b suggests that, during the transition period, the symbols l^I, b^I should be used for the old system and l^{II}, b^{II} for the new one. The Commission also strongly recommends that, apart from these superscripts, it should be made quite clear whether the galactic coordinates used in any publication are based on the old or the new system.

Basis for choice of new system.—The new system is intended to be oriented, as closely as is now practicable, so that the pole is perpendicular to the mean plane of the Galaxy and the circle of zero longitude passes through the galactic centre. The pole position was based primarily on the distribution of neutral hydrogen in the inner parts of the Galaxy ($R<7$ kpc, assuming $R_{Sun}=8{\cdot}2$ kpc); the most precise evidence on the galactic centre came from the location of the radio source Sagittarius A, which is presumed to be the galactic nucleus. It remains a problem for future investigation to determine to what extent more exact positions of the layer of neutral hydrogen and the galactic nucleus deviate from the quantities adopted for the present revision. However, it may be expected that these deviations are small and will not give rise to further revisions of the galactic coordinate system in the near future.

The new method of specification of the zero of longitude in terms of its position angle has been chosen because this angle is one of the quantities used directly in conversion formulae from equatorial to galactic coordinates.

The equatorial plane of the new coordinate system must of necessity pass through the Sun. It is a fortunate circumstance that, within the observational uncertainty, both the Sun and Sagittarius A lie in the mean plane of the Galaxy as determined from the hydrogen observations. If the Sun had not been so placed, points in the mean plane would not lie on the galactic equator.

A report will soon be published giving details of the Commission's investigations.

Conversion tables.—In accordance with a decision taken at the Moscow Assembly, conversion tables from equatorial into galactic coordinates and vice versa, and from the old and new galactic coordinate systems into each other, will soon be published under the supervision of Commission 33b.

The members of Sub-Commission 33b

A. BLAAUW
C. S. GUM
J. L. PAWSEY
G. WESTERHOUT

1959 *March* 25

ARTIFICIAL SATELLITES

I. The Motions of Artificial Satellites

1. *Introduction.*—This report is limited, rather narrowly, to the astronomical information that can be obtained from observations of the positions and motions of artificial satellites of the Earth. Studies of artificial satellites on radio wavelengths are the subject of a separate note.

Positional observations may be used in three quite different ways:

(*a*) as a measure of parallactic shift to provide information on the relative positions of observers on the Earth;

(*b*) as a means of determining the instantaneous orbit and thus the secular variations of the elements of the orbit;

(*c*) as a means of determining the position of the satellite in its orbit.

The motion of an artificial satellite is essentially governed by the non-spherical gravitational field of the Earth and by the resistance due to air drag and electrical effects caused by the Earth's atmosphere; perturbations by the Sun, Moon, and other planets are very small. For use (*a*) as geodetic beacons a knowledge of the actual motion is required over only short intervals of time; for satellites close to the Earth simultaneous, or nearly simultaneous, observations may prove useful even if the position and motion are not accurately known. The unknown effects of atmospheric resistance need not therefore be serious. The secular variations of the orbital elements in (*b*) depend almost entirely either on the effects of atmospheric resistance or on the asymmetry of the Earth's gravitational field. Thus, analysis of the rates of decrease of period and eccentricity has already led to improved knowledge of the density of the atmosphere for heights up to several hundred kilometres, and has shown its great variability with position and time; and analysis of the observed rates of precession of the orbital plane (retrogression of the node) has indicated a correction of about 0·3 per cent to the adopted value of the dynamical flattening, or oblateness, of the Earth. The actual position of a satellite as in (*c*) depends on accurate evaluation of both perturbing effects; since accurate prediction of atmospheric resistance is impracticable in the case of low satellites, the observed motion can be used only for detailed studies of atmospheric characteristics. However, for a satellite whose perigee distance is sufficiently large for atmospheric resistance to be small enough to be predicted, the comparison of the observed with the calculated motion will be of the greatest interest to astronomy, and may lead to a new and powerful method for the determination of ephemeris time. The prediction and analysis of such motions presents many difficult problems of both theory and analysis; and accurate observations of such fast-moving objects require special techniques. The existence of observable artificial satellites, with accurately predicted orbits (in the same way as for the minor planets), may also be of significance for problems of geodesy and navigation.

Most of the papers so far published are concerned only with preliminary investigations of the problems of theory, observation and analysis, and it is to be expected that many more detailed discussions will be published in the near future. No attempt has therefore been made to give a complete bibliographical

coverage, and only a few selected references to readily accessible journals are given. Further, this report has been restricted to a general survey of the results obtained and of the demands on theory and observational technique that are likely to be made in the future.

No attempt has been made to discuss space probes as it is unlikely that their motions can be observed sufficiently accurately for their orbits to yield new information on the gravitational field of the Earth, or of the solar system.

2. *Orbital data.*—The principal physical characteristics and orbital elements of artificial satellites launched up to February 1959 are given in the accompanying table, which is based on a similar table issued by the Royal Aircraft Establishment. No data are given in respect of the radio transmitters, telemetering systems or other instruments carried.

3. *Parallactic shift.*—There is no record of any results having so far been obtained from observations of artificial satellites treated as geodetic beacons; although, to some extent, the transit observations from the Minitrack and Moonwatch stations form an extreme case of this application. The more straightforward applications, such as the theoretically possible method of determining position at sea by a single observation without reference to the vertical, depend on a knowledge of the position of the satellite in its orbit; predictions to the requisite precision are not possible with existing satellites.

4. *Secular orbital variations.*—For low satellites, that is for satellites with small perigee distance, the most important secular variations of the elements are due to atmospheric resistance. This results in a decrease of the period (the rate of decrease increasing as the period decreases), a corresponding decrease in the semi-major axis with a proportionally larger decrease in distance at apogee than at perigee, and thus in a decrease in the eccentricity of the orbit. Estimates of the life-time of such satellites can be made on the basis of simple theories, in spite of the fact that the day-to-day motions of the satellites are so erratic that precise predictions cannot be made even a few days in advance.

The orbital plane of a satellite precesses, independently of atmospheric resistance, because of the departure of the Earth's gravitational field from spherical symmetry. The longitude of the node of the orbit on the equator retrogrades at a rate proportional to the cosine of the inclination and to the mean distance to the power $-7/2$; the rate therefore increases as the mean distance decreases. The theoretical expression contains terms dependent on the coefficients of the spherical harmonics in the expression of the gravitational potential of the Earth (19):

$$U=\frac{fM}{R}\left\{\frac{R}{r}+J\frac{R^3}{r^3}\left(\frac{1}{3}-\sin^2\phi'\right)+D\frac{R^5}{r^5}\left(\sin^4\phi'-\frac{6}{7}\sin^2\phi'+\frac{3}{35}\right)\right\}$$
$$+\sum\sum\frac{A_{ns}S_{ns}}{r^{n+1}}$$

where S_{ns} are the spherical surface harmonics P_{ns} (cos $s\lambda$, sin $s\lambda$). The rate of precession can be accurately determined over a long period even from comparatively crude observations; analysis of the differences between the observed and computed values have already shown (18) that the currently adopted value of J is too large, corresponding to a change in the coefficient of dynamical flattening from 1/297 to 1/298. This change is nearly three times the standard error of the previous determination from gravity measurements. Further data are rapidly

ARTIFICIAL SATELLITES

Physical Characteristics

Ref. No.	Designation	Name and description	Launching date; life-time; descent date	Mass	Size d=diameter l=length	Maximum visual magnitude
1	1957α2	Sputnik 1 instrumented sphere	1957 Oct. 4 ? 92 days ? 1958 Jan. 4	83 kg	d=58 cm	+5
2	1957α1	Sputnik 1 rocket	1957 Oct. 4 57 days 1957 Dec. 1	?	d=? l=?	−1
3	1957β	Sputnik 2 instrumented rocket	1957 Nov. 3 162 days 1958 Apr. 14	? payload =508 kg	d=? l=?24 m	−3
4	1958α	Explorer 1 instrumented rocket	1958 Feb. 1 4 years	14 kg	d=15 cm l=2 m	+6
5	1958β2	Vanguard 1 instrumented sphere	1958 Mar. 17 ? 200 years	1·5 kg	d=16 cm	+8
6	1958β1	Vanguard 1 rocket	1958 Mar. 17 ? 100 years	23 kg	d=51 cm l=1·2 m	+5
7	1958γ	Explorer 3 instrumented rocket	1958 Mar. 26 93 days 1958 June 28	14 kg	d=15 cm l=2 m	+6
8	1958δ2	Sputnik 3 instrumented cone	1958 May 15 600 days	1327 kg	d=1·7 m l=3·8 m	+1
9	1958δ1	Sputnik 3 rocket	1958 May 15 202 days 1958 Dec. 3	?	d=? l=?	−3
10	1958ε	Explorer 4 instrumented rocket	1958 July 26 450 days	17·5 kg	d=15 cm l=2 m	+6
11	1958ζ	Atlas instrumented rocket	1958 Dec. 18 33 days 1959 Jan. 21	3856 kg	d=3 m l=24 m	−3
12	1959α1	Vanguard 2 instrumented sphere	1959 Feb. 17 ? 100 years	9 kg	d=56 cm	+6
13	1959α2	Vanguard 2 rocket	1959 Feb. 17 ?	23 kg	d=51 cm l=1·2 m	+5

Notes.—(i) The material in this table has been compiled from a variety of sources, and is not intended to be definitive.

(ii) ? denotes that the value is unknown or is very uncertain.

OF THE EARTH

Equatorial orbital elements

Ref. No.	Date	Inclination	Nodal period	Semi-major axis	Eccentricity	Daily motion of perigee	Daily motion of node	Height (km) perigee	Height (km) apogee
		°	m			°	°		
1	1957 Oct. 5	65·1	96·2	1·090	0·052	−0·4	−3·1	213	936
	Oct. 26	65·1	95·4	1·084	·047	0·4	3·2	209	860
	Dec. 25	65·0	91·0	1·051	·020	0·5	3·4	191	458
2	1957 Oct. 5	65·1	96·2	1·090	0·052	−0·4	−3·1	213	936
	Nov. 4	65·1	94·0	1·074	·038	0·4	3·2	208	734
	Nov. 24	65·0	91·0	1·051	·020	0·5	3·4	191	458
3	1957 Nov. 4	65·3	103·7	1·147	0·099	−0·4	−2·6	213	1659
	1958 Jan. 4	65·3	100·5	1·123	·080	0·4	2·8	208	1357
	Feb. 21	65·3	97·1	1·097	·060	0·4	3·0	198	1043
	Mar. 25	65·2	93·8	1·072	·040	0·5	3·2	185	732
	Apr. 9	65·2	90·8	1·049	·022	0·5	3·4	167	456
4	1958 Feb. 1	33·2	114·8	1·228	0·139	+6·3	−4·3	369	2541
	1959 Jan. 3	33·1	111·7	1·206	·125	6·8	4·4	348	2276
5	1958 Mar. 17	34·3	134·1	1·362	0·191	+4·4	−3·0	654	3966
	1959 Feb. 12	34·2	134·1	1·361	·190	4·4	3·0	654	3953
6	1958 Mar. 17	34·3	138·5	1·391	0·208	+4·0	−2·8	649	4338
7	1958 Mar. 27	33·3	115·7	1·234	0·166	+6·3	−4·3	187	2800
	Apr. 25	33·3	109·7	1·191	·136	7·0	4·7	185	2251
	June 14	33·3	96·8	1·096	·063	9·2	6·2	172	1047
8	1958 May 15	65·2	106·0	1·165	0·111	−0·3	−2·5	213	1868
	Oct. 1	65·2	104·0	1·151	·101	0·4	2·6	211	1685
	Dec. 9	65·2	102·5	1·140	·092	0·4	2·7	209	1547
9	1958 May 15	65·2	105·8	1·163	0·111	−0·4	−2·5	213	1861
	Aug. 15	65·1	102·0	1·134	·089	0·4	2·7	208	1499
	Oct. 11	65·1	98·0	1·104	·066	0·4	3·0	200	1127
	Nov. 14	65·0	94·0	1·074	·041	0·5	3·2	187	752
	Dec. 1	65·0	90·0	1·043	·017	0·5	3·5	163	389
10	1958 July 27	50·3	110·2	1·194	0·128	+2·9	−3·6	263	2211
	1958 Oct. 25	50·3	107·7	1·176	·115	3·1	3·7	259	1987
	1959 Jan. 3	50·3	105·3	1·159	·103	3·4	3·9	259	1766
11	1958 Dec. 19	32·3	101·3	1·130	0·090	+8·6	−5·7	180	1480
	1959 Jan. 2	32·3	98·1	1·106	·071	9·1	6·0	175	1177
	Jan. 17	32·3	92·7	1·065	·037	10·1	6·7	163	662
12	1959 Feb. 17	32·9	125·7	1·304	0·166	+5·3	−3·5	558	3323
13	1959 Feb. 17	32·9	130·0	1·333	0·184	+4·9	−3·3	558	3691

(iii) The semi-major axis is in units of the Earth's equatorial radius, 6378 km.

(iv) The heights of perigee and apogee are above a sphere of radius 6378 km. For a latitude ϕ these heights should be increased by about $(21{\cdot}4 \sin^2 \phi)$ km.

being accumulated and it is desirable to wait until they have been discussed before a definitive value of J, as derived from satellite observations, is adopted; satellites of differing inclinations are required to separate the corrections to J and D.

Evaluation of the coefficients of the other harmonics, especially those depending on longitude, depends on the comparison of the observed and predicted *positions* of the satellite.

The oblateness of the Earth is also responsible for the motion of the perigee along the orbit. The principal term in the theoretical expression for the secular variation of the argument of perigee (the arc from the ascending node on the equator to perigee) contains the term $(0{\cdot}2-\cos^2 i)$; for orbits with inclinations i greater than 63° the motion is thus retrograde. For the Sputniks, for which the inclination is near 65°, the motion of the perigee is small. The position of perigee cannot easily be determined accurately from observation, and no detailed comparison of observation with theory has yet been published.

The inclination is, to a first approximation at least, theoretically unaffected by either atmospheric resistance or gravitational asymmetry. But the actual inclinations are observed to decrease gradually. It has been suggested that this is due to a component of air drag, normal to the direction of motion, caused by the rotation of the atmosphere with respect to the orbital plane (**14**). It is essential that possible atmospheric effects should be fully investigated, and allowed for, in the secular variations of the node and perigee before the results derived from the observed values are adopted.

The variations of the magnitude of non-spherical satellites lead to determination of their attitudes and rotational motions. The secular changes in these motions imply changing effective cross-sectional areas and so complicate the interpretation of the air drag effects.

5. *Positional data.*—The motions of the artificial satellites so far launched, as distinct from the positions of their orbital planes, are so disturbed by irregularities of atmospheric resistance that no precise astronomical information has yet been obtained. The applications of such data for satellites not subject to such disturbances are considered in **Section** 8.

6. *Precision of observations.*—Owing to the high linear and angular speeds of the satellites the determination of the time of observation is as critical as the determination of position—in one millisecond of time a satellite travels about 8 metres and up to 5 seconds of arc. However, observations suitable for maintaining a prediction service and for establishing the principal secular changes in the elements of an orbit require accuracies only of the order of 1 degree in arc and 1 second in time. Such observations can be made by estimating by eye the position of a satellite with respect to bright stars near its track and noting the times from an accurate watch. A more accurate and elaborate method is provided by the Moonwatch programme, organized by the Smithsonian Astrophysical Observatory, and by similar programmes in other countries. A team of observers with small telescopes is used to establish the time of transit of a satellite across the meridian. The method is primarily intended for finding faint satellites.

Observations of great value have been obtained by the use of kinetheodolites. These are special cameras mounted on an altazimuth mounting. The satellite is tracked visually and photographs of the satellite with respect to a grid and of the

altitude and azimuth scales defining the centre of the grid are obtained at 1/5 second intervals. The accuracy of a single observation is of the order of 0°·01 and timing accuracy is of the order of 0ˢ·01. The principal advantage of this type of observation is that a sufficiently long arc of the orbit can be observed so that the elements of the orbit can be obtained directly at a single passage of a bright satellite.

Observations of the highest precision are obtained by the use of Baker-Nunn satellite tracking cameras. As in meteor cameras the trail of a satellite on a star-field is interrupted to establish a time-scale. Each plate gives a position with a probable error of about 4″ and a timing accuracy of about 0ˢ·002. Precise observations obtained by these and similar cameras should be of great value in establishing accurate orbits of high satellites and hence for applications to geodesy and time determination.

For low satellites conventional astronomical telescopes are of little value owing to the great angular speed of track and the lack of precise predictions, but are likely to be of value for high satellites especially as such satellites will be faint.

Radio and radar observations have the great advantage that they are not restricted to times of favourable weather conditions during twilight passages of the satellites, but the angular accuracy is low. This is particularly true of positions based on transmissions from the satellites at 20 and 40 Mc/s, as the ionospheric refraction may be so great as to render the observations useless. At 108 Mc/s, however, an accuracy of 0′·3 in position and 0ˢ·001 in time is expected from, for example, the American system of Minitrack stations.

7. *Theories of satellite orbits.*—Atmospheric resistance and the oblateness of the Earth give rise to distinct first-order effects and so, up to the present time, have been treated independently. This is only justified for close satellites because the variability of atmospheric resistance (due to varying aspect of the satellite, varying densities and other factors) renders useless any accurate theory. For more distant satellites, for which atmospheric resistance is sufficiently small to be treated theoretically, it will probably be justifiable to include it independently, possibly at the same time as the perturbations by the Moon. The perturbations of the elements of an elliptic orbit due to motion in a resisting medium are treated in many standard text-books on celestial mechanics (e.g. **(17)** and **(15)**); the specific application to artificial satellites of the Earth is considered in references **(14)** and **(16)**.

The theory of the motion of a particle in the field of a spheroid has not been fully treated in astronomical literature since in the few cases arising in the solar system the observations are so difficult that they can be adequately represented by a simple theory. The theory of the motion near the equatorial plane of a non-spherical body has, however, been developed by Brouwer **(6)** in connection not only with the orbit of Jupiter V and similar satellites but also as an introduction to the motion of close binary systems, consisting of two spheroids of comparable masses. The effect of the oblateness of the Earth on the motion of the Moon has, of course, been fully discussed by G. W. Hill and E. W. Brown.

The first- and second-order solutions that have so far been published have been adequate for the analyses of the observations of past satellites. However, it may be noted that the work of King-Hele **(10)**, who has been responsible for much excellent work in maintaining a prediction service for the British Isles during 1958 and in analysing visual observations made primarily in British Isles,

does not follow conventional astronomical methods or usage, though Öpik (**11**) has obtained many of King-Hele's results, or their equivalents, by the application of the method of variation of elements.

Sterne (**13**) and Garfinkel (**8**) have introduced expressions for Hamiltonians, approximating to the actual Hamiltonian of the attraction of a spheroid, which lead to closed solutions. These solutions give much better representations of the actual orbit than does a Keplerian ellipse, and yet retain many of the advantages of the latter. It is not yet clear whether these will be suitable for the development of an accurate theory.

Brouwer (**7**) has shown that his earlier work, based on the Hill-Brown lunar theory, may be extended to non-equatorial orbits. He has also considered Delauney's method and his preliminary investigations have shown that although it offers the perfect analytic solution the complex operations required do not lend themselves to machine calculations. He estimates that an accurate general theory for an individual satellite is of the same order of difficulty as that for a major planet.

Herget and Musen (**8**) are investigating the possible applications of Hansen's method and it is understood that preliminary conclusions will be published in the *Astronomical Journal*. A first-order solution by a similar method has been given by Roberson (**12**).

It is clear from these investigations that the artificial satellites will provide celestial mechanics with a range of problems that will require many years for their satisfactory solution, and that theories that have been superseded for the orbits of natural satellites must be re-examined for their suitability for these new problems.

Satellites whose orbits extend to the distance of the Moon afford a particularly difficult case of the three-body problem, even if only the restricted three-body problem is considered. The possible orbits of such a " lunar probe " have been treated in considerable detail by Yegorov (**3**) who has been forced to adopt numerical integration procedures. The conditions for the establishment of a satellite in a periodic orbit about the Earth and Moon are so critical and the difficulties of observation are so great that it seems likely that numerical integrations will suffice for many years.

In general, numerical integration of the equations of motion will provide an essential check on theoretical methods but will not suffice for long-term investigations, such as those concerned with the determination of time. The periods are so short that the intervals used will have to be very small and building-up errors will soon get out of control.

8. *Applications.*—For distant satellites for which atmospheric perturbations are so small that they can be accurately allowed for in the discussion of the observations (this implies a minimum perigee distance of at least 1000 km above the Earth's surface) the following information of astronomical and geodetic importance should be obtainable, provided that the physical characteristics allow observations of adequate precision to be made.

(*a*) *Ephemeris time.*—Ephemeris time is defined by means of the motion of the Earth in its orbit round the Sun (which moves through $1''$ of longitude in 24^s of time) but determined in practice by the motion of the Moon in its orbit round the Earth ($1''$ of longitude $= 1^s{\cdot}8$). For an artificial satellite with mean distance $(1+x)$ Earth radii, $1''$ of longitude $= 0^s{\cdot}004\,(1+x)^{3/2}$, so that for reasonable values

of x the precision of time determination from determinations of longitude of comparable accuracy is 300 times that for the Moon. Observations should be possible (if possible at all) with both greater precision and greater frequency than with the Moon; and at closest approach there is a further factor of about 5 between the precisions of observation and of longitude. The precision of the determination of the second is proportional to the precision of the normal places obtained by grouping the observations and to the time-interval between them: a precision of about 3×10^{-10} (of the same order as that at present possible for the frequency of the caesium resonator) should theoretically be obtainable from observations spread over a few months. This assumes precisions of the normal places of about $1''$ and a timing accuracy of $0^{s}{\cdot}001$, corresponding to a precision of about 5 metres in actual position.

The practical difficulties, apart from those of observation, are formidable. Even when an adequate theory of the motion is available, observation over an extended period will be necessary to relate the independent time variable of the theory to ephemeris time. The comparison of the time-scale defined by the satellite itself with, say, that of caesium should, however, provide interesting information.

(*b*) *Fundamental reference systems.*—The possibility of using fast-moving artificial satellites in the determination of the fundamental reference system should not be overlooked. However, apart from the difficulties of observation, very highly accurate theories of motion would be necessary.

(*c*) *Gravitational field of the Earth.*—Observations of position, especially of satellites in orbits at different inclinations to the equator, should provide data from which the coefficients of the higher harmonics in the Earth's gravitational field, especially those depending on longitude, can be determined. According to O'Keefe and Batchlor (**21**) the effect of the term $P_2^2 \cos 2\lambda$, which is the largest that depends on longitude, will give rise to perturbations of the order of $5''$ of orbital longitude; the coefficient should be reasonably well determined if observations of the precision assumed are possible. The principal terms, which give rise to secular variations in the elements, will of course be well determined, especially as observations can be combined over long intervals.

(*d*) *Geodetic positions and navigation.*—An observable satellite, whose position can be accurately predicted to a few tens of metres can clearly be used for determination of position on the Earth in many ways. Details are not discussed here.

9. *Desired orbital characteristics.*—Although it would be possible to specify the orbital characteristics, and possibly the physical characteristics as well, desirable for a satellite intended solely for the purely astronomical role considered above, it is certain that other factors will predominate. For a long time, astronomers will have to make use of the satellites as they come; all that can be done is to urge that all feasible steps be taken to make them readily observable by optical methods.

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ARTIFICIAL SATELLITES

II. Radio Studies of Artificial Satellites

The successful launching of radio transmitters into the upper atmosphere in the first Russian satellites stimulated a wide variety of radio observations, designed for the complementary purposes of determining the satellite orbits and to study the propagation of radiowaves through the ionosphere and atmosphere. After a period of vigorous activity, a re-assessment of the experimental possibilities is now resulting in the careful planning of more deliberate experiments.

The early radio experiments provided information on (i) the orbit of the satellites, (ii) their rotation, (iii) the total electron content of the ionosphere, and (iv) irregularities in the ionosphere. The radio signals also carried a vast quantity of telemetered information about temperature, meteor impact, cosmic rays, etc. Apart from the telemeter code itself, the characteristics of the radio signal which can now be measured are the direction of arrival of the radio wave, its frequency, its polarization, and its strength. If the propagation were rectilinear, the orbit could be determined either from the direction or the frequency, since the latter shows a characteristic Doppler shift following a variation which gives the minimum range and the time of closest approach for each transit of a satellite. Ionospheric information can correspondingly be found either from comparison of these radio measurements with those expected from an actual orbit, or from a study of extra characteristics imposed on the radio signal as it traverses the ionosphere. One prominent effect is the rotation of the plane of polarization due to the Faraday effect, which depends primarily on the total electron content along the line of sight, and on the component of the Earth's magnetic field along that line; another is the " scintillation " caused by a random diffraction in ionospheric irregularities.

Orbital information.—Radio observations of the tracks of a satellite, made solely to determine its orbit, are particularly useful in the early part of its lifetime, before the more accurate optical tracking gets under way. For Sputnik 1 there was at first very little organized observation outside U.S.S.R., and radio tracking provided the only accurate information for over a week. The first detailed orbital information published came from radio data only (Mullard Observatory 1957) and included good determinations of the rate of change of period and the regression of the nodes. After the radio transmitter stopped this satellite was lost, with visual observations continuing on the rocket carrier.

The fading of the radio signals from Sputnik 1 was used by Thomson (1958) to determine the axis and rate of rotation through its lifetime.

Ionospheric studies.—The propagation path from a satellite intercepts the ionosphere from a varying height and direction. For an ionosphere which is horizontally stratified and three measurements of refraction, Faraday rotation, and departures from the simple Doppler effect all relate to the same quantity, the total electron content along the path of propagation. All these measurements are in practice much complicated by horizontal gradients in the ionosphere and by irregularities both on a large and a small scale. To distinguish various complications along the path measurements are planned using a satellite carrying simultaneous transmitters on harmonically related frequencies.

Radio stars are observed to " scintillate " at longer radio-astronomy wavelengths, due to diffraction in irregularities of the F-region of the ionosphere. The

geographical distribution and height of these irregularities has now been found during successive passages of Sputnik 1 within 1000 miles of Cambridge (Kent 1959). This method is very potent as the transmission path sweeps rapidly over a large area of sky, with successive tracks acting as an evenly spaced scan.

Summaries of the radio observations on the Russian satellites were given in a Royal Society discussion and at the Institute of Electrical Engineers. References are given below. Some Russian work has been reported by Krassovsky (1959) and a survey of the possible methods of ionospheric research has been made by Berning (1959).

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SOLAR ACTIVITY

Sunspots.—The level of solar activity again remained very high during 1958. The peak of the present maximum phase occurred at about the beginning of the year but the mean Zurich relative sunspot number fell only to 184·8 following the 1957 value of 190·2, the highest annual mean yet recorded.

For three months, viz., January, August and September, the mean number exceeded 200.

In November, however, a sharp but temporary drop in activity took place and, for a short period in the middle of the month, there were fewer spots on the Sun than at any time for more than two years.

Both 1957 and 1958 have proved outstanding in the number of groups observed. These exceeded by an appreciable margin the number for any maximum period during the past two centuries. During 1958 sixty groups exceeding 500 millionths of the visible hemisphere in area were observed at Herstmonceux, only one less than in 1957. Twenty-one of these had maximum areas exceeding 1000 millionths.

The largest, which crossed the disk between March 1 and 14 (Central Meridian Passage March 7·4) in latitude 17°S, reached a maximum area of 2200 millionths.

Solar flare activity also remained at a high level, particularly during March, July and August, although the Fraunhofer Institute *Daily Maps of the Sun* record only 13 flares ≥ Importance Class 3 during the year out of a total of more than 2500 flares ≥ Class 1.

The only flare of Class 3+ observed at Herstmonceux occurred on March 3 from 1016–*1115* U.T. (position: 17°S, 62°E) and was associated with the large group mentioned above. This flare was accompanied by a large sudden enhancement of atmospherics and a complete fadeout, but was not followed by any geomagnetic effects.

The number of sudden enhancements of atmospherics (SEA's) on 27 kc/s and sudden ionospheric disturbances (SID's) fell during the year, despite several active periods, notably one in March.

SID's reported by Cable and Wireless Ltd. numbered just over 100, or two-thirds of the 1957 total.

Cosmic radiation activity also fell off during the year, nothing recorded approaching the level reached in September and October, 1957.

P. S. LAURIE

Prominences.—The mean daily areas and numbers of prominences at the limb as derived from photographs taken at Kodaikanal are as follows:

	Area in square minutes					Number				
1958	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	3·94	1·89	2·93	2·90	5·83	5·41	3·62	4·44	4·59	9·03
July–Dec.	3·69	2·28	2·90	3·07	5·97	5·51	4·32	5·02	4·81	9·83
Whole year (weighted mean)	3·85	2·05	2·93	2·97	5·90	5·45	3·91	4·68	4·68	9·36

Compared to 1957 there has been a slight increase in activity judged in terms of both areas and numbers, the increase in areas being 14·5 per cent and that in numbers 6·2 per cent.

The distribution of areas in 5° ranges of latitude shows two peaks of activity in the northern hemisphere in the zones 35°–40° and 70°–75° while in the southern hemisphere the maximum activity is in the zone 30°–35°. Both numbers and areas indicate that the activity in the southern hemisphere has continued to be less than in the northern hemisphere.

Doppler displacements of the H-alpha line in prominences and absorption markings observed with the prominence spectroscope and the spectrohelioscope are summarized below:

	North	South	East	West	To red	To violet	Both ways	Total
Prominences	61	44	56	49	2	—	103	105
Dark markings	25	18	22	21	1	1	41	43

The heights of 25 fairly tall prominences were measured in H-alpha, D_3 and H-beta lines with the prominence spectroscope. These were compared with the corresponding heights in K-line as obtained from the spectroheliograms. The average heights were:

K	H-alpha	D_3	H-beta
102″·4	90″·0	77″·7	70″·1

There were six occasions of sudden disappearances of absorption markings on the disk or of prominences on the limb.

The mean daily areas and numbers of hydrogen dark markings on the disk as obtained from Kodaikanal records are as follows:

	Area in millionths of the Sun's visible hemisphere (uncorrected for foreshortening)					Number				
1958	North	South	East	West	Total	North	South	East	West	Total
Jan.–June	2927	1939	2345	2521	4866	15·74	11·93	13·60	14·07	27·67
July–Dec.	2584	2259	2066	2777	4843	17·12	14·09	14·50	16·71	31·21
Whole year (weighted mean)	2796	2084	2238	2642	4880	16·32	12·84	13·98	15·18	29·16

Compared to the previous year, the mean daily area shows a slight decrease of 3·1 per cent while in the case of numbers there is an increase of 3·2 per cent. The distribution of areas in 5° ranges of latitude shows a maximum in the zone 35°–40° in the northern hemisphere and in the zone 25°–30° in the southern hemisphere. The activity in the southern hemisphere is considerably less than in the northern. The western preponderance in areas and numbers observed last year has continued.

A. K. DAS

COMETS (1958)

Thirteen comets were under observation during 1958, but none of these was brighter than eighth magnitude. In addition to the two comets of small eccentricity which are observed annually, there were two new comets, three periodic comets whose return had been predicted, and six previous discoveries. Reports of observations have been unusually few during the year, the lion's share of the work being done by Dr Elizabeth Roemer, using the 40-inch reflector of the U.S. Naval Observatory at Flagstaff, Arizona. This instrument is very favourably placed for the observation of faint comets, and Miss Roemer's contributions to this work are of the very first importance. Extensive observations are also made by Van Biesbroeck at Yerkes and McDonald Observatories and by Jeffers at Lick, but otherwise comets are very much neglected. There is, however, considerable observational research on comets in the U.S.S.R., and in 1958 positions or physical measurements of seven comets are given for ten observatories in the Russian *Astronomical Circulars*.

Comet Schwassmann-Wachmann 1925 II was recorded at Flagstaff, Lick and McDonald, and has continued to show fluctuations of structure and brightness. On August 12 it had a sharp nucleus with only a faint coma, but on August 15 the nucleus appeared diffuse with a broad fan extending to 10″ from the nucleus, total magnitude 13·5. By September 12 the magnitude was near 18, and the coma diffuse, but on September 22 the image was nearly stellar, magnitude 15, with only the faintest trace of coma. There was another outburst at the end of November (Van Biesbroeck), confirmed by a series of photographs at Flagstaff, when the total magnitude reached 14·0, which is three magnitudes above normal brightness. At the beginning of December the coma was more than 1′ in diameter with a clearly defined nucleus, but by December 10 the comet had faded noticeably. On December 4 N. U. Mayall obtained a spectrogram of the comet using the Crossley reflector at Lick; the spectrum was of the solar type with no emission features.

Comet Oterma, 1942 VII, has remained as a faint object throughout the present period. It was photographed at McDonald and Flagstaff in January, when it had a short tail, and again in April when it had a well condensed nucleus of magnitude 18; this is confirmed by photographs at Lick in April and May. At the end of the year it was again photographed at Flagstaff and was then of magnitude 18·8 with a trace of a tail to the N.W. Several papers of outstanding interest on the subject of this comet have recently appeared. Dr Liisi Oterma of Turku, Finland, has computed a definitive orbit for this comet (which is the third of three comets which she herself discovered in 1942–1943) and has studied its past history and future behaviour. It appears that the present 8-year period resulted from a prolonged approach to Jupiter in the period 1936–1939, when the comet's distance from the planet decreased to 0·17 unit. The previous orbit had a period of 18 years, with a perihelion distance of 5·65 a.u. as compared with the present 3·40 a.u. The circumstances will repeat themselves in the years 1962–1964, and this time the closest approach to Jupiter will be 0·095 a.u. in 1963 April. As a result, the comet's orbit will be enlarged once more, with an

increased eccentricity and a period of 19 years. A paper on the same subject by A. Fokin in *Bull. Inst. Theor. Astr.* (Leningrad) **7**, (2), also gives a definitive orbit and carries the perturbations back to 1936. The original orbit is stated to have had a period of 23 years.

Some idea of the changes in the orbital elements may be gained from the following approximate values, derived from Oterma's papers:

	a	e	π	Ω	i	Period
1934	6·86	0·18	283°	35°	3°	18·0 years
1950	3·97	0·14	150	155	4	7·9 ,,
1965	7·17	0·25	23	333	2	19·2 ,,

Since the perihelion distance in the future orbit will be as much as 5·35 a.u. it is certain that this faint comet will be lost to moderate instruments after 1962. It is to be hoped that the largest telescopes will be able to follow its departure from the present orbit.

1954 k, Haro-Chavira, was under observation at Flagstaff from February to May. On May 15 the comet was near opposition, at a heliocentric distance of 7·7 a.u., and appeared on 90-min exposures as a weak nearly stellar nucleus of magnitude 20·9; there was a very faint nebulosity about 0′·5 diameter.
(*Observations* 1954 *December* 17 *to* 1958 *May* 15)

1956 c, Wirtanen, continued to show a double nucleus throughout the year. In January (McDonald) and February (Flagstaff) the nuclei were separated by about 20″ and were of magnitudes 16·5 and 18. At both stations and at Lick a faint tail was reported in April and this continued to be present until the end of July. In April and May there seems to have been an emission of material from the sunward side of the primary nucleus. By the end of the year the nuclei had separated to about 25″, and were last photographed at Flagstaff on December 11 at low altitude, magnitudes 18·5 and 19·0. The comet should be observable in the spring of 1959 after conjunction.
(*Observations* 1956 *March* 16 *to end of* 1958, *continuing*)

1956 h, Arend-Roland, was photographed on January 25 by Van Biesbroeck, using the 82-inch reflector at McDonald Observatory. The comet was estimated at magnitude 20 and showed a faint coma. Photographs at Flagstaff in January and March were made under conditions of poor seeing, but on April 11 exposures of 90-mins gave measurable images of magnitude 21·0.
(*Observations* 1956 *November* 8 *to* 1958 *April* 11)

1957 d, Mrkos, was well south of the equator, and observations in the northern hemisphere were difficult. In such circumstances reports from southern observatories are always welcome, and in this connection it is gratifying to be able to correct an error in last year's report on this comet. Observations were made at the Perth Observatory from 1957 August 30 to October 21, and the positions obtained appear in *UAIC* 1629. These accurate positions will be most valuable, and it is to be hoped that the observers at Perth will be able to continue with such work.

Comet Mrkos was observed at Johannesburg on 1958 February 21 and March 2, but all other reports come from Van Biesbroeck (McDonald, January 27), Jeffers (Lick, April 26), or Miss Roemer (Flagstaff, February 17–July 19). The comet faded from about magnitude 16 at the beginning of the year. In April and May it had a well-condensed nucleus (magnitude 18) with an unsymmetrical coma of about 0′·2 diameter. Conditions for observation, with the comet in declination −31°, were far from ideal; the last photographs were taken on July 9, when the magnitude on 60-min exposures was estimated at 19·0.
(*Observations* 1957 *July* 29 *to* 1958 *July* 9)

1957 e, P/Reinmuth (1), was photographed at Flagstaff and McDonald in January; it then appeared as a somewhat diffuse coma about 0′·1 diameter, magnitude 18. In April (Lick) the appearance was that of a diffuse spot of magnitude 18·5; there was still a faint trace of coma surrounding a nearly stellar nucleus, magnitude 18·8, on May 15 (Flagstaff).
(*Observations* 1957 *September* 20 *to* 1958 *May* 15)

1957 g, P/Harrington (1), was again observed after perihelion passage in August. At McDonald the comet had a faint narrow tail 1′ long on the west side of a diffuse nucleus. At Flagstaff the nucleus appeared more strongly condensed, but the tail was also reported and the same general appearance continued during succeeding months, as the comet faded from magnitude 16·5 to about 18·6.
(*Observations* 1957 *November* 18 *to end of* 1958, *continuing*)

1958 a was discovered by Robert Burnham Jr., an amateur of Prescott, Arizona, on February 21–22, as mentioned in last year's report. Burnham was using a new 8-inch reflector at his home, and at once notified the Lowell Observatory, whose co-operation enabled Miss Roemer to photograph the comet within two hours of the discovery.

The visual magnitude of the comet at the time of discovery was about 9, but it was much fainter than this photographically. Observations were widely made in Europe and the U.S.A. At Heidelberg, Richter gave the total brightness as magnitude 9·1 in March, 8·5 to 8·8 in April, and this agrees with the customary careful observations of Max Beyer at Hamburg–Bergedorf. Using a law of the type $m = H_0 + 2{\cdot}5n \log r + 5 \log \Delta$, Beyer finds from 25 observations over the period April 6 to June 18 that $H_0 = 6{\cdot}72 \pm 0{\cdot}27$ and $n = 7{\cdot}36 \pm 0{\cdot}74$. Thus even a sixth-power law would be inadequate to represent the changing brightness of this comet. We seem to be as far as ever from a solution of the problem of the luminosity of comets, and this is undoubtedly due to a lack of observational material.

The comet was followed at Flagstaff until September. In its early stages (March 10) it had a centrally condensed coma about 2′·5 diameter with a narrow straight tail 12′ long directed eastwards. The tail was still visible in mid-May, when the total brightness reached magnitude 8·2 and the well-defined nucleus was surrounded by a coma of 4′ diameter (Van Biesbroeck). The comet faded rapidly after this and had reached magnitude 17 on August 20 (McDonald) and 19 on September 15 (Flagstaff).

A Sonneberg Sky Patrol plate taken on February 10 was found to contain a pre-discovery image.
(*Observations February* 10 *to September* 15)

1958 b, periodic comet Arend–Rigaux, was recovered by Dr Roemer on January 29 on the second of a series of search plates centred at $\Delta T = +2^d$ and $+5^d$ from Candy's ephemeris in the *B.A.A. Handbook*. The stellar image was confirmed on later plates, and the faint comet (magnitude 19 at recovery) was followed until June 7. The magnitude was then 20·5, and the comet was not found on a 90-min exposure on July 8. The comet at the time of recovery was well past perihelion, and observations indicate that Haségawa's predicted orbit in *UAIC* 1566 was in error by only $\Delta T = -1{\cdot}5$ days.
(*Observations January* 29 *to June* 7)

1958 c, periodic comet Wolf (1), is the object of continuous research by Kamienski, and its recovery on June 13 is particularly gratifying. Exposures of 90 mins at Flagstaff during May had failed to locate the comet, but at the suggestion of Dr Roemer, a pair of plates was taken by W. A. Baum with the 200-inch telescope at Palomar, centred on positions computed by Roemer. Both plates showed the stellar image of the comet, magnitude 20·4, and subsequent plates at Flagstaff confirmed the recovery. In September the comet was in a rich star-field, but plates taken in October show probable images of the comet. Two good exposures of 90-mins on November 9, using 103a-D plates developed in metol sulphite showed no trace of the comet, which was then moving clear of the Milky Way. Kamienski's ephemeris of P/Wolf (1) was in error by only $0^s{\cdot}3$ and $1''$, and it is hoped to locate it again in the autumn of 1959.
(*Observations June* 13 *to October* 14 (?))

1958 d, periodic comet Kopff, was recovered on the nights of June 25–26 by Dr Roemer at Flagstaff. The comet, photographed at low altitude through the branches of a tree, showed a diffuse image not fainter than apparent magnitude 18·8. It was photographed in July (Flagstaff), August (McDonald and Lick) and September (Lick), and displayed a round coma $0'{\cdot}3$ in diameter, magnitude 18·5. By October it had faded below 20th magnitude and the images on plates taken in November and December at Flagstaff were very diffuse and nearly at the plate limit; the estimated magnitude was 21·6.

The recovery of this comet is a matter of some importance. The close approach to Jupiter in 1954 caused serious changes in the orbit, the line of nodes being moved through 130°, so that the orientation of the plane of the orbit is completely altered. Although the orbit remains of the same size and shape, and the longitude of perihelion is little changed, the new orbit is inclined at nearly 11° to the old one. Kepinski's careful work on this comet has been rewarding, and emphasises once again the necessity of using accurate initial elements in such cases of close approach to Jupiter. It is also clear that a suitable perturbation method must be used; Kepinski's prediction was within 10^s and $1'$ of the observed position of the comet, and this can only be due to the particular care with which he computed the perturbations. He writes that he proposes to recompute them,

using intervals decreasing to 1·25 days in a Jovicentric system, in order to link the three apparitions of 1945, 1951 and 1958.
(*Observations June 25 to December 4*)

1958 e was the second new comet of the year, and was discovered by Robert Burnham Jr. and Charles D. Slaughter on a plate taken on September 7 with the 13-inch telescope at Lowell Observatory in the course of a systematic survey of proper motions in the northern hemisphere. The first plates of this survey were made in the autumn of 1929, forming part of the programme for the discovery of Pluto in 1930, and continuing so as to cover the entire sky with this instrument. It is to be noted that the first cometary discovery of 1959 was also due to these two young astronomers working on the same proper-motion survey.

Comet 1958 e was a diffuse object of magnitude 14 at the time of discovery; it had a well condensed nucleus with a coma 0′·7 diameter and a short tail pointing south of east. The tail was also visible in October, but by November 10 the comet had merely a strong nuclear condensation set off-centre in a round coma. The comet was brighter in December, with a nucleus of magnitude 15·8 (Roemer) and total brightness (Van Biesbroeck) 13·5, the observations being made at low altitude. Systematic observations of position were also made during this period by observers at Skalnaté Pleso.
(*Observations September 7 to end of year, continuing*)

Unsuccessful searches were made during 1958 for the following comets :

P/du Toit-Neujmin-Delporte. Skalnaté Pleso (July 11, 12 to magnitude 17); McDonald (10-inch Cooke lens, August, to magnitude 16); Palomar (48-inch Schmidt, April 13); Lowell (13-inch, July, September to magnitude 16); Johannesburg (May, June, July, October).

1957 f, Latyshev-Wild-Burnham. Flagstaff (January, February to magnitude 19); McDonald (January, February); Johannesburg (February).

P/Harrington-Wilson. Flagstaff (February to magnitude 19); Palomar (48-inch Schmidt, April 12–13 to magnitude 20).

P/Ashbrook-Jackson. Flagstaff (February 11 to magnitude 20–21).

P/du Toit (1). Flagstaff (December and in 1959, continuing).

The numerical designation of comets (in order of perihelion passage) has been extended by the I.A.U. Bureau (*UAIC* 1662). The list that follows continues that given in *M.N.* **118**, 399, 1958. The perihelion dates (*T*) are from orbits noted in these annual reports.

Comet	*T*	Name	Year and letter
1955 I	Feb. 27·1	P/Schwassmann-Wachmann (2)	1954 g
II	Mar. 4·6	P/Faye	1954 e
III	June 4·2	Mrkos	1955 e
IV	July 11·5	Bakharev-Macfarlane-Krienke	1955 f
V	Aug. 4·1	Honda	1955 g
VI	Aug. 13·2	Baade	1954 h
VII	Sept. 27·4	P/Perrine-Mrkos	1955 i
VIII	Nov. 29·8	P/Whipple	1955 d

Elements of

Ref.	Comet	T (U.T.)	q	e
(1)	1931 II P/Encke	1931 June 3·1136*E*	0·331867	0·849786
(1)	1934 III P/Encke	1934 Sept. 15·2816*E*	0·331861	0·849806
(1)	1937 VI P/Encke	1937 Dec. 27·7538*E*	0·332391	0·849604
(1)	1941 V P/Encke	1941 Apr. 17·1513*E*	0·341369	0·846175
(2)	1941 VII P/du Toit-Neujmin-Delporte	1941 July 21·2208*E*	1·305008	0·582987
(3)	1942 VII P/Oterma	1942 Aug. 22·1947	3·389461	0·144431
(4)	1945 V P/Kopff	1945 Aug. 11·2676	1·495674	0·556076
(1)	1947 XI P/Encke	1947 Nov. 26·3263*E*	0·341026	0·846290
(5)	1948 VIII P/Forbes	1948 Sept. 16·1212*E*	1·545253	0·552716
(6)	1948 XII P/Honda-Mrkos-Pajdušáková	1948 Nov. 17·7086*E*	0·559024	0·814293
(7)	1949 V P/Väisälä	1949 Nov. 11·2782	1·752058	0·635232
(8)	1953 I Harrington	1953 Jan. 5·4170	1·664975	0·995947
(9)	1953 VI P/Harrington (2)	1953 Sept. 22·1628	1·694081	0·536031
(6)	1954 III P/Honda-Mrkos-Pajdušáková	1954 Feb. 5·1067*E*	0·555646	0·815126
(10)	1954 IV P/Van Biesbroeck	1954 Feb. 20·8099*E*	2·414935	0·550031
(11)	1955 VIII P/Whipple	1955 Nov. 29·6926	2·449952	0·355800
(12)	1956 b Mrkos	1956 Apr. 13·6092*E*	0·842240	1
(13)	1956 c Wirtanen	1957 Sept. 2·338	4·44611	1·00086
(14)	1958 b P/Arend-Rigaux	1957 Sept. 8·29*p*	1·38539	0·61070
(15)	1958 d P/Kopff	1958 Jan. 20·077*p*	1·516199	0·556223
(16)	1958 a Burnham	1958 Apr. 16·3041*E*	1·322625	1
(17)	1957 g P/Harrington (1)	1958 Aug. 11·830*p*	1·604438	0·539881
(18)	1958 e Burnham-Slaughter	1959 Mar. 11·527*E*	1·628380	1
(19)	1958 c P/Wolf (1)	1959 Mar. 21·824*p*	2·506895	0·394754
	Predicted orbit			
(20)	P/Encke	1961 Feb. 5·583*p*	0·339017	0·847056

REFERENCES AND NOTES TO TABLE OF ELEMENTS

(1) P/Encke. S. Y. Luchich, *Bull. Inst. Theor. Astr.* (Leningrad), **7**, (2), 1958. Definitive elements.

(2) P/du Toit-Neujmin-Delporte. B. G. Marsden, *UAIC* 1652. From 24 Uccle observations 1941 August 19–October 12, confirming the definitive elements of N. F. Boeva (*M.N.*, **111**, 242, 1951)

(3) P/Oterma. A. V. Fokin, *A.J.* (*U.S.S.R.*), **35**, 675, 1958. From 127 observations 1943–1950 at 7 oppositions, Jupiter and Saturn perturbations included. See also *Bull. Inst. Theor. Astr.* (Leningrad), **7**, (2), 1958.

(4) P/Kopff. F. Kepinski, *Acta Astr.*, **7**, (2), 1957. Definitive.

(5) P/Forbes. B. G. Marsden, *MS.* From 13 observations 1948 May 4 to October 2 in 5 normals, assuming the period given by Cripps; Jupiter perturbations included.

(6) P/Honda-Mrkos-Pajdušáková. B. G. Marsden, *MS.* From 19 observations 1948 December 7 to 1949 January 10 and 28 observations 1954 January 28 to April 1.

(7) P/Väisälä. L. Oterma, *MS.*

(8) 1953 I, Harrington. J. E. Forbes, H. Spinrad and D. B. Wood, *A.J.*, **63**, 510, 1958. Improved orbit from 3 observations, comparison with 15 others; arc of 292 days, Jupiter perturbations.

(9) P/Harrington (2). C. Dinwoodie, *MS.* Improved orbit, using 5 observations 1953 August 15 to December 10.

Cometary Orbits

Period (years)	ω	Ω	i	Equinox	Epoch	Ref.
3·28	184°·9133	334°·8974	12°·5633	1950·0	1931 June 28·0 E.T.	(1)
3·28	184·9452	334·8823	12·5604	1950·0	1934 July 22·0 E.T.	(1)
3·29	184·9393	334·8810	12·5488	1950·0	1937 Nov. 30·0 E.T.	(1)
3·31	185·1599	334·7634	12·3505	1950·0	1941 Feb. 15·0 E.T.	(1)
5·54	69·3394	229·6123	3·2604	1950·0	...	(2)
7·89	354·7883	155·1679	3·9898	1950·0	1943 Oct. 3·0 U.T.	(3)
6·18	31·5393	253·1185	7·2228	1950·0	1945 July 4·0 U.T.	(4)
3·30	185·1820	334·7502	12·3524	1950·0	1947 Oct. 22·0 E.T.	(1)
6·42	259·7387	25·4443	4·6207	1950·0	1948 Sept. 6·0 E.T.	(5)
5·22	184·1047	233·0918	13·1632	1950·0	1948 Nov. 25·0 E.T.	(6)
10·53	44·3340	135·4651	11·2804	1950·0	1949 Feb. 13·0 U.T.	(7)
8326·5	191·6307	220·7322	59·1201	1953·0	1953 Jan. 23·0 U.T.	(8)
6·98	219·3820	136·6205	11·6009	1950·0	...	(9)
5·21	184·1410	233·0836	13·1950	1950·0	1954 Jan. 18·0 E.T.	(6)
12·43	134·3373	148·9757	6·5905	1950·0	1954 Sept. 25·0 E.T.	(10)
7·42	190·4345	188·5091	10·2507	1950·0	as T	(11)
...	81·0098	226·1081	147·4555	1956·0	...	(12)
...	13·263	232·944	33·200	1950·0	...	(13)
6·71	326·405	124·648	17·200	1950·0	1957 June 15·0 U.T.	(14)
6·32	161·7203	120·9975	4·7078	1950·0	1957 Jan. 2·0 U.T.	(15)
...	16·4596	150·6178	15·7920	1958·0	...	(16)
6·51	187·0288	254·2266	18·4790	1950·0	1958 Sept. 24·0 U.T.	(17)
...	100·7334	323·2066	61·2598	1959·0	...	(18)
8·43	161·0780	203·9045	27·2975	1950·0	1959 Mar. 13·0 U.T.	(19)
3·30	185·2271	334·7214	12·3597	1950·0	1960 Dec. 12·0 U.T.	(20)

(10) P/Van Biesbroeck. G. Van Biesbroeck, *A.J.*, **63**, 500, 1958. Definitive, with predicted elements for 1966.

(11) P/Whipple. C. Dinwoodie, *MS.* Improved orbit, using 6 observations, 1955, comparison with 22 others.

(12) 1956 b, Mrkos, B. G. Marsden, *B.A.A.J.*, **68**, 124, 1958. From 32 observations 1956 March 13 to May 5 in 4 normals.

(13) 1956 c, Wirtanen. I. Haségawa, *UAIC* 1665. Observations 1956 March to 1958 November; no perturbations.

(14) P/Arend-Rigaux. I. Haségawa, *UAIC* 1566. Observations suggest $\Delta T = -1{\cdot}5$ days.

(15) P/Kopff. F. Kepinski, *Acta Astr.*, **8**, (4), 1958. Predicted elements derived from the 1951 orbit with perturbations by six planets.

(16) 1958 a, Burnham. B. G. Marsden, *UAIC* 1651. From 3 observations, arc of 31 days.

(17) P/Harrington (1). J. Kordylewski, *Acta Astr.*, **8**, (2), 1958; perturbations by Jupiter and Saturn.

(18) 1958 e, Burnham-Slaughter. M. P. Candy, *UAIC* 1661. From 3 observations September 7, October 4, November 4.

(19) P/Wolf (1). M. Kamienski, *Acta Astr.*, **7**, (1), 1957.

(20) P/Encke. S. G. Makower, *MS.* Based on the elements of *B.A.A. Handbook* 1957 with perturbations Mercury to Saturn.

The elements of cometary orbits recently computed are tabulated on pp. 442/443 in order of perihelion passage T. Ephemeris Time has been used in those cases marked E; all other times are in U.T. The symbol p indicates predicted elements only.

Additional Notes

Individual Comets

P/Halley. M. Kamienski, *Acta Astr.* Vol. 8. The past history of the comet is considered in relation to historical references.

P/Wolf (1). M. Kamienski, *Ibid.*

P/Oterma, 1942 VII. A. V. Fokin, *Bull. Inst. Theor. Astr.* (Leningrad), **7,** (2), and *A. J.* (*U.S.S.R.*), **35,** (4). The references to the papers of L. Oterma were given in last year's report.

P/Schwassmann-Wachmann (1). E. Roemer, *P.A.S.P.*, **70,** 272, 1958. An account of the outbursts of this comet.

P/Encke. S. Y. Luchich, *Bull. Inst. Theor. Astr.* (Leningrad), **7,** (2). The author shows that the secular acceleration of Comet Encke cannot be explained on Mokhach's hypothesis that it may be due to systematic errors of observation.

P/du Toit-Neujmin-Delporte. A. S. Sochilina, *Bull. Inst. Theor. Astr.* (Leningrad), **6,** (9). See *M.N.*, **118,** 397, 1958, reference (16).

1956 h, Arend-Roland. G. Larssen–Leander, *Ark. für Astr.* Bd 2, (23), 259, 1958. (*Stockholm Medd.* 111). Physical observations of the comet with some excellent photographs and bibliography.

General

Computers of the Warsaw and Cracow observatories, under the direction of Kamienski, are investigating the orbits of periodic comets Perrine-Mrkos, Harrington (1) 1952 II, Grigg-Skjellerup and Giacobini-Zinner. In the U.S.S.R., Galibina has investigated the original and future orbits of some long-period comets: *Bull. Inst. Theor. Astr.* (Leningrad) **6,** (9). Both Vsessviatsky and Orlov have published books on comets (in Russian) during the year. Vsessviatsky, Babuch and Kazutinsky discuss the capture theory of the origin of short-period comets in *A. J.* (*U.S.S.R.*) **35,** (3); they conclude that the hypothesis is inconsistent with the observed distribution of orbits. Steins has derived criteria governing the capture of comets from a parabolic orbit, assuming plane motion: *A. J.* (*U.S.S.R.*), **35,** (1)

J. G. PORTER.

THE PRESIDENT'S ADDRESS ON THE AWARD OF THE GOLD MEDAL TO DR RAYMOND ARTHUR LYTTLETON

Dr W. H. Steavenson

The Society's Gold Medal has this year been awarded to Dr Raymond Arthur Lyttleton for his work on the stability of rotating fluid masses, on the constitution and evolution of the stars, and on the origin and peculiarities of the Solar System.

In awarding the Medal to one of its own members, the Council has followed a precedent set on several previous occasions, the last being in 1942; for it has long been felt that an individual who happens to be giving long service to the Society as a member of the Council should not thereby be debarred from receiving equal consideration along with all other possible recipients of the Medal.

To turn now to Lyttleton's actual work, I can say at once that it spans almost the whole of theoretical astronomy, and is especially remarkable for standing, in several fields, at the beginning of a revival of interest in that field. In a number of instances his work has laid the foundations on which a great amount of subsequent research has rested. His first significant contribution came while he was at Princeton as the Procter Visiting Fellow from Cambridge. At that time, with H. N. Russell as professor, Princeton was an especially stimulating place; and in addition to all his other great merits, Astronomy is indebted to Russell for having secured, for good it seems, Lyttleton's interest in our subject.

One of the most tantalisingly obscure problems of theoretical astronomy was then, as it is now, the question of the origin of the Solar System. In 1936 all theories were completely on the rocks; but Lyttleton in his first major paper showed how the famous angular momentum difficulty could be surmounted in the mode of formation from a binary star, a hypothesis already suggested by Russell, but dismissed by him as involving insuperable objections. At the same time Lyttleton began to examine the various peculiar features of the Solar System that might afford clues to its origin and development. He was particularly interested in accounting for the rotations of the planets and their satellites; and he was the first to develop the hypothesis that Pluto might be an escaped satellite of Neptune.

On returning to England, Lyttleton chanced to become acquainted with Hoyle, just then embarking on a career as a theoretical physicist. He soon began to interest Hoyle in the sort of astronomical problems that were engaging his own attention; and in this way Lyttleton may be said to be the founder of the whole modern Cambridge school of theoretical astronomy.

The two main problems that Lyttleton and Hoyle attacked in the next few years, despite the calls made on their time by war work, were the constitution and evolution of the stars. Before 1938, much attention had been given to the theory of stellar structure in this country by Jeans, Eddington, Milne, Cowling and others. However, all this earlier work was seriously retarded and made difficult and restricted by the then lack of certain knowledge as to the nature of the source of stellar energy. In 1938, Bethe, partly in collaboration with Critchfield, practically solved this problem from the point of view of nuclear physics, but it remained to fit it into the scheme of stellar theory. Lyttleton and Hoyle were

the first to see how this long-awaited piece of information could be applied, and they developed the theory of stellar structure anew on this basis. The first triumph of their theory was to make perfectly clear the position of Eddington's important but obscure " mass-luminosity relation ", and it was Lyttleton and Hoyle who first obtained the true mass-luminosity and mass-radius relations. Shortly afterwards, they turned to problems more difficult than those of the main-sequence stars, and they were the first to give a viable theory of red giant stars.

In the field of stellar evolution, Lyttleton and Hoyle were the first really to appreciate the importance of the interstellar medium to the stars. It is perhaps hard to realise nowadays, when through radio-astronomy and other means so much is known and published about interstellar hydrogen, that, when they first postulated its existence twenty years ago, they had to do so in the teeth of a highly incredulous active opposition from those who were certain that interstellar space must be empty of gas, except perhaps for a few calcium atoms. In this way Lyttleton and Hoyle shed a completely new light on the question of star formation and stellar evolution. Though the problems involved are difficult, and their solution still obscure, it is clear that their intervention brought an entirely new order of development to the subject.

After the War, Lyttleton felt that the moment had come when he could find time to set out his considered conclusions on the classical problem of the stability of rotating fluid masses. With H. F. Baker, he was one of the very few people who had made a thorough study of the vast and forbidding technical literature of this subject, and Lyttleton was certainly the first to appreciate the whole problem in the light of the contributions of Liapounov and Cartan. His monograph on this, published in 1953, remains for the present the last word on this century-old intricate matter, and is a model of rigour and lucidity.

At much the same time, as a by-product of the famous accretion theory, Lyttleton had been led to take up the subject of comets, which from the theoretical side had long been neglected. His entirely novel theory of the formation of these objects throws a fresh light on these numerous but hitherto little-studied members of the Solar System. He has also put this work into book form, and the new interest of this past ten years in the theory of comets dates from his first papers on this subject, communicated to this Society.

Mention should also be made of Lyttleton's important work in theoretical geophysics. He was the first to appreciate the hydro-dynamical significance of the fluid core of the Earth, and the influence it must have on nutation and similar phenomena. Once again his contributions marked the beginning of a new phase of interest and activity in a subject that had almost come to a stop, whereas the end of the resulting developments is not yet in sight.

Dr Lyttleton, it gives me great personal pleasure to hand this Medal to you. On many occasions in the past it has been bestowed towards the end of an astronomer's career, in recognition of the labours of a lifetime. I need hardly say that in your case the Council does not regard the award in this light. On the contrary, it is made in the confident hope that, in the years to come, you will continue to add to the achievements which have already earned this mark of our appreciation.

THE PRESIDENT'S ADDRESS ON THE AWARD OF THE EDDINGTON MEDAL TO DR JAMES STANLEY HEY

Dr W. H. Steavenson

The Eddington Medal has been awarded by the Council to Dr James Stanley Hey for his outstanding discoveries concerning radio emission from the active Sun, radio reflections from meteors, and discrete sources of cosmic radio emission.

In his whole history down to our own times, man has had only one window, the optical window, through which he could study the heavens. He has learned only in our generation that a second, the radio window, exists, because he has only in that time acquired the means of seeing through it. But even after the existence of this window became known it was not immediately appreciated that a new view of the heavens is to be had through it. It fell to one man more than anyone else to discover this, to grasp its significance and to stimulate others to see for themselves. J. S. Hey has this special place in the history of our science.

There were some half-dozen basic discoveries that have led to the whole development of radio astronomy as we know it to-day. Hey played the principal part in no less than three of these. With his own team he was the first to identify radio-noise from a sun-spot area, he was the first to show that it is possible to study meteors by means of radar, and he was the first to discover a discrete radio-source (that now known as Cygnus A).

Before Hey's unique contributions, there had been only three sets of experiments on cosmic radio-emissions, those of Jansky, Reber and Southworth. None of these stimulated the interest they deserved, and it was not through them that Hey was led to radio-astronomy. It was, instead, his appreciation of the scientific implications of war-time observations that led him to his major discoveries.

The discovery of metre-wavelength radiation from sunspots resulted in 1942 from Hey's critical examination, as a member of the Army Operational Research Group, of reports of noise reception by sensitive radar receivers.

The second discovery, that of radar echoes from meteor trails, also originated from war-time radar observations. There had been suggestions that abnormal ionization in the E-layer of the atmosphere is of meteoric origin and that certain transient radar echoes are caused by meteors. But the connection had not been established and still less had anyone previously thought of using the radar observations to study the meteors themselves. Hey realized that shorter wavelengths than those previously used were needed to clear up the matter. As soon as possible after the war, using modified Army radar equipment made to operate at 4–5 metres, Hey and his collaborators made their well-known series of observations of the *Lyrid* and *Quadrantid* meteor showers that decisively settled the question, and that very soon led to extensive observations by other workers.

This work was not a matter of merely looking through the radar window. It was, so to say, a matter of shining a searchlight through it and so discovering something about astronomical objects other than the Earth by man-made agencies. Hey is therefore not only a chief pioneer in a new method of observation, but we may recognize him also as the first experimental astronomer of all time.

Hey's third basic discovery was made after the war during a still more deliberately planned investigation in 1946–48 in which the distribution of cosmic radio-noise was plotted over the northern sky. This investigation further established Hey's position as a true pioneer by showing how his previous work of brilliant interpretation was now being followed by original and fruitful observational astronomy. The new feature that Hey and his colleagues noted was a fluctuation of the radio-noise from the direction of Cygnus, from which they concluded that there must be in this region a high intensity source subtending a small angle. Thus was born the least expected but most significant development in radio astronomy, its provision of means of studying the universe in the large. In this room we have listened to many papers and discussions on the far-reaching outcomes of this one discovery.

Besides these basic discoveries, Hey had made other notable contributions. For instance, in 1942 Appleton and Hey independently got the first indications of enhancements of radio emission associated with solar flares, and they later jointly discovered the association of peaks of radio-noise with solar flares and ionospheric fade-outs. Hey also made one of the first attempts to secure a spectrum of solar radio-noise. Again, he and his team made the first radar determination of meteor velocities.

The development and employment of the equipment needed for all these researches has required the co-operation of skilled and resourceful collaborators, and Hey would be the very first to recognize their share in the successes we have been discussing. But one of the qualitities in Hey that we should like to recognize to-day is his ability to lead a scientific team. He has now for some time been the head of a group at the Royal Radar Establishment that is pursuing a most interesting series of experiments on short wavelength radio star emission, high resolution interferometry, and radar echoes from the Moon.

From the start, Hey's work has been done with far-seeing appreciation of its significance. It has been vastly extended by other workers. This extension is not only a tribute to its importance, but it has also served to demonstrate many times over the soundness of the foundations laid by Hey himself.

Dr Hey, by the bestowal of this Medal we recognise the great value of your services to the new science of Radio Astronomy; and at the same time we offer to you our cordial good wishes for success in your future labours in this field.

AN ADDRESS BY THE PRESIDENT
THE INSTRUMENTS OF SIR WILLIAM HERSCHEL

Dr W. H. Steavenson

Early in 1958 it became known that Observatory House, at Slough, would soon be passing out of the hands of the Herschel family, and that many of the instruments made and used by our first President, and left by him in the care of his descendants, would be offered for sale. Up to the present the house remains unsold; but the second part of the plan has been carried out, and the various astronomical instruments have found new and probably permanent homes. It therefore seems to me that this would be a suitable occasion for giving a brief description of the relics thus dispersed, and for putting on record the present whereabouts of the principal items of the collection.

Much has already been published with regard to Herschel's instruments. In particular, we have the astronomer's own description of some of the more important of them, to be found in various papers which originally appeared in the *Philosophical Transactions* of the Royal Society, and which were reprinted in two volumes published by that Society and our own in 1912, under the title of *The Collected Scientific Papers of Sir William Herschel.* The Preface to these two volumes also contains some useful notes by the Editor, the late J. L. E. Dreyer. Finally, a descriptive list of the surviving instruments, the result of an examination of them which I made in 1924, was published in a special " Herschel Number " of the *Transactions of the Optical Society* in 1925 (1). Later, during the thirties, several of the items there described were presented by the late Rev. Sir J. C. W. Herschel to the Science Museum, and nearly all of those that remained were sold by auction at Sotheby's in March 1958.

When I examined the collection in 1924, it consisted of (1) the two 48-inch mirrors of the 40-ft telescope, and a part of its tube; (2) the tube of the 20-ft telescope and one of its three mirrors; (3) a few smaller objective mirrors; (4) a number of flats, eyepieces and micrometers; (5) some pieces of mechanical apparatus used in connection with the two large telescopes; (6) a complete 7-ft telescope on its original mounting. This afternoon I shall confine my remarks to the purely optical items, taking them in the order just given.

Mirrors of the 40-foot telescope.—Two 48-inch mirrors of speculum metal were made for this instrument. The first, through a fault in the casting process, was unsymmetrical in the distribution of the metal, and for this reason and through being generally too thin, it was found that it would not keep its figure when placed in the telescope. It was therefore soon laid aside on the completion of a thicker and more satisfactory mirror; but neither Sir William himself nor his son Sir John seem to have left any written account of what was actually done with it when it was thus superseded. By 1924 all that remained as a guide to its whereabouts was a family tradition that it lay concealed somewhere on the premises of Observatory House; and it was decided that a search should be made for it. As it was not to be found in any of the outhouses or cellars, it was concluded that it must lie buried somewhere in the grounds. Some tentative excavations were therefore made, but all that came to light was one of the great cast-iron disks that had been used for the grinding of one or both of the mirrors.

Later, in 1927 (**2**), some measurements were made in the "Cottage", a small building which at one time was surmounted by the flat roof on which Caroline Herschel discovered her eight comets; and it was noticed that there was a considerable space under the stairs, to which there was no visible means of access. After a preliminary inspection, made through a hole cut in the boards of the upper landing, the whole staircase was cut in half, to reveal the missing mirror, leaning against one of the side walls. It was rolled on its edge to one of the ground-floor rooms, and there examined after its sheet-iron cover had been removed. When the thick coating of dust had been wiped off, the polish, dating from 1797, was seen to be in excellent condition. It was not practicable to make a test of the mirror's figure, nor does Herschel's own experience of its performance suggest that such a test would have been worth making. The mirror was presented by Sir John Herschel to the Science Museum, where it can now be seen.

The second 4-ft mirror was much more successful in actual use, being a good deal more massive. The disk was cast with a convex rear surface, so that it was of approximately equal thickness all over. It was polished for the last time in 1809, and was already much tarnished at the time of its maker's final observation with it in 1815. From that time onwards it remained in the telescope, with the tube in a horizontal position. It was still there in 1840, when Sir J. F. W. Herschel moved from Slough to Hawkhurst, leaving Observatory House and its grounds in the hands of tenants. But in 1867 a severe gale brought a large tree down onto the tube, which was only 0·7 mm thick, and completely destroyed a large part of it. Fortunately the mirror escaped damage, and was immediately removed from the 10-ft section which still remains, and was mounted vertically against the wall in the entrance hall of Observatory House. Here it rested until last year, when it came into the possession of the National Maritime Museum at Greenwich.

Here, for the first time, it was possible, by setting it up temporarily at the end of one of the long galleries, to get at its centre of curvature, and make a rough test of the figure. With the kind permission and co-operation of the Director, Mr Frank Carr, who is a Fellow of our Society, I did what was possible in this way on the occasions of a few visits to the Museum in the recent autumn and winter. It may be imagined that, after nearly sixty years' exposure in the open air between 1809 and the date of its removal indoors, the mirror was greatly tarnished, and there was actual chemical erosion over the whole surface. But there was still some semblance of a polish, and on 1958 September 30 an image of a sort was obtainable with the help of an electric torch and a pinhole. However, there were signs of violent astigmatism, and examination under a knife-edge showed that this was due to localized pressure on the disk in its stout iron cell. It was then found that the cruciform iron framework holding the mirror in the cell was pressing against it with considerable force. This pressure was greatly reduced by a loosening of three of the four bolts holding the cross-bar, with the result that, when I made the next test in November, a large part of the flexure had disappeared. But a final test was postponed until the fourth bolt, which was awkwardly placed at the time, could be reached and loosened. This was done on 1959 February 4, when I was able to make a final test, with the mirror freed from all constraint in its cell. The result was rather disappointing. Apart from an annulus about four inches wide all round the edge of the mirror, the surface had a rough and uneven appearance, due mainly to deterioration of the polish, while

patches of tarnish made a zonal test impossible. Judged by an eyepiece test, the general figure appeared roughly spherical; but there was still some astigmatism, which was probably the end effect of the long-continued pressure, though the signs of acute flexure, observed earlier, had disappeared. A sharp image of a pin-hole, probably produced by the peripheral annulus, was obtained with a power of 900; but it was surrounded by a mass of scattered light, contributed by the uneven central parts of the mirror.

The surviving 10-ft section of the tube of the 40-ft remains for the time being in the garden of Observatory House.

A mirror of the 20-foot telescope.—This is one of three mirrors formerly used with the telescope. With the other two, it was taken to the Cape and used there by Sir J. F. W. Herschel and the present figure of all three must therefore be due to him. It was tested by Foucault's method on 1923 June 26 by the Rev. C. D. P. Davies, Sir J. C. W. Herschel and myself, under a slowly rising temperature (3). The figure was found to be markedly hyperbolic, the linear aberrations at the centre of curvature being about five times as great as they should have been for a paraboloid. The mirror was tested again by me on 1924 May 14 under a slowly falling temperature. The figure was then found to be still more hyperbolic, the aberrations being a little more than double those noted on the earlier occasion. In spite of these marked departures from a parabolic figure, it is probable that, in view of its great focal ratio (1 : 13·3), the mirror performed quite well with the low and medium powers commonly used with it in the observation of nebulae and clusters. Of the other two 20-ft mirrors, one is now at the Royal Observatory at the Cape, and the other, which was presented towards the end of last century to the Radcliffe Observatory, is now, with the third, at the National Maritime Museum.

Smaller objective mirrors.—Several mirrors, mostly of about 7 ft or 10 ft focal length, were found in 1924, all together in a partitioned wooden box. An inventory of the contents of this box, made by Sir J. F. W. Herschel in 1840, mentions that, of the mirrors therein, " one is the Georgian ", which means presumably that with which the planet Uranus was discovered. Unfortunately there was no trace of this mirror, and it is not known what became of it between 1840 and 1924.

Of the mirrors which remain, two are of special interest, being of glass. They were no doubt made by Herschel for work on the Sun, and each was mounted in a brass cell, on a bed of black velvet. One, of about 7 ft focal length, had a diameter of 6·7 inches, while the other was a 10-ft with a diameter of 8·5 inches. Both were sensibly spherical in figure, and no zonal test was attempted.

Finally, there were three 10-ft mirrors of speculum metal, each of which was in a soldered container of tinned iron. They probably represented the remains of Herchel's stock of such things, still unsold at the time of his death in 1822; and they were probably put into their respective cases some years before this. When the cases were unsoldered in 1924, the polish of all three mirrors was found to be almost perfect. Each had a figured surface of 8·8 inches diameter, and a focal length of almost exactly 10-ft. Under the knife-edge the appearances were remarkably similar, the figure of all three being sensibly spherical. A notable feature of these and nearly all Herschel's mirrors was their general smoothness of figure, with an almost complete absence of zonal irregularities. In this respect they are in marked contrast with the two 24-inch mirrors of Lassell,

which I tested at the Royal Observatory, Greenwich about 30 years ago. These mirrors showed a number of fine rings in nearly identical positions, and it seems likely that this was the result of incorporating a system of cog-wheels in the mechanism used in the polishing of the mirrors. Herschel's apparatus was more simple, but gave a more uniform figure to his specula.

All these smaller mirrors were presented to the Science Museum by Sir J. C. W. Herschel, with the exception of one of the 10-ft metal mirrors, which was given to me by Sir John. It is now on loan to the Royal Greenwich Observatory.

Flats, eyepieces and micrometers.—There were some 30 elliptical plane mirrors of the type commonly supplied by Herschel with the telescopes he made for sale. Most of them were of the standard diameters adopted for 7-ft and 10-ft telescopes, and were of minor axis 1·1 or 1·5 inches respectively. Each consisted of a solid casting of speculum metal, soldered to a brass disk for attachment to the single support adopted by Herschel in all his Newtonians. Most of the flats were supplied with close-fitting cylindrical covers of thin brass, and their polish was in good condition. No critical examination of their surfaces was made; but a rough test was effected by using them to reflect the rays from an artificial star into the objective of a small refractor. The resulting images were not sensibly impaired, which indicates that they were at least reasonably good planes.

There were, in all, 48 eyepieces, some mounted in brass and others in cocus wood. With one doubtful exception, probably not the work of any of the Herschels, each contained a single lens, generally of equi-convex form. This lens was in most cases held in position between the two cylindrical portions of which the brass or wooden mounting consisted. It seems probable that those lenses which were of more than 0·1 inch focal length were not made by Herschel himself, but were procured in bulk from some London optician.

But this was certainly not the case with the nine eye-pieces of exceptionally high power. These deserve special mention as the most interesting items in the whole collection of eyepieces. Their focal lengths, measured with a microfocometer, were found, to range between 0·064 and 0·011 inch. (4) Each lens was set between two domed plates of thin brass, gripped between the two threaded portions of a small mount of cocus wood. These are evidently the eyepieces of very high power, for the use of which Herschel was at the time much criticized in scientific quarters. But Herschel himself, in a paper communicated to the Royal Society, made it quite clear that these eyepieces of excessively high power were used only for experimental purposes, and not for his regular observational work. It had been suggested in some quarters that Herschel might have made some mistake in the estimation of the magnifying powers; but my own measurements showed that these were substantially the same as he had claimed, ranging from 1300 to over 7500 on the 7-ft telescope with which he had used them. His main object was to establish the fact, noted by him long before, that the apparent diameter of a star-image did not increase in exact proportion to the magnifying power. But, for most of us, the most significant thing emerging from Herschel's experiments will be that he could see anything at all with such powers. It is in fact conclusive proof that he could and did produce, at least on occasion, mirrors of excellent figure. This is in itself remarkable, considering that none of the modern tests was available to him. His method of trying out his mirrors was to examine the stonework of Windsor Castle with the peripheral and central portions of the mirror alternately exposed. When the foci of both parts agreed,

the mirror was judged to be good. We do not know at what time of day he commonly made these tests, but it was most probably in the late afternoon, when the best definition of terrestrial objects is generally to be obtained. If this is so, the temperature would be falling, so that the more massive mirrors would tend to become, for the time being, over-corrected. The small change of figure required to turn a spherical surface of focal ratio between 1 : 13 and 1 : 14 into a paraboloid might well be effected by such a falling temperature, and this may account for the apparent absence of correction in the three 10-ft mirrors mentioned earlier. With less massive mirrors the effect would be smaller, so that Herschel's 7-ft mirrors, of about 6½ inches diameter, may have had a more nearly parabolic figure.

There were, in 1924, nine eyepiece micrometers, five of which were in cocus wood mountings. The working parts were all of brass, with the exception of the steel distance screws. The frames were originally fitted with silk threads, and some of these were still in place. The machining work in connection with these micrometers, and also all the eyepieces, was done on Herschel's own lathe, which in 1924 was still in working order. In the case of the telescopes made for sale, the greater part of this mechanical work was probably done by William's brother Alexander. Some of the micrometers are now at the National Maritime Museum.

The 7-ft telescope.—This is the only complete instrument in the collection. With its mahogany tube and altazimuth mounting, it is probably the one described by Herschel as being " fitted up commodiously for my own use ". The clear aperture of the mirror in its brass cell is 6·2 inches, and its focal length 7 ft 2¾ in. When tested by Foucault's method, under a slightly rising temperature, the surface was found to be beautifully smooth from centre to edge, with no trace of zonal irregularities. There was a slight amount of under-correction under the existing conditions. In the evening the telescope was tested on various celestial objects, the eyepiece used being one of Herschel's own, consisting of a single bi-convex lens, giving a power of about 360. The temperature was falling steadily, and the mirror now showed a very slight degree of over-correction, as judged from the appearances of out-of-focus star-images. The performance was in every way excellent, and, from the point of view of definition, quite equal to that of any good modern reflector of similar aperture. Stars showed clearly defined disks, with diffraction rings, and the central craterlet in Plato was very plainly seen. The only defect was in the light-grasp which, through tarnishing of mirror and flat, was no better than that of a 3-inch refractor. Herschel evidently knew what he was doing when he set this telescope aside " for his own use ". This beautiful instrument was not sold along with the others, but remains in the possession of a great-great-granddaughter of the man who made it.

We are really very fortunate in having so many tangible memorials of Sir William Herschel available for the inspection of all; and there are of course many other specimens of his handiwork in various institutions and museums, both in this country and abroad; for the telescopes which he made for sale found their way into many parts of Europe. But, after all, the fame of Herschel does not depend on the preservation of his instruments; and I may here cite an oft-quoted remark made by his son on presenting our Society's Gold Medal to

Francis Baily. Its reference was to the position of a star, determined with a meridian instrument; but it surely has a wider application:

> "When once its place has been thoroughly ascertained and carefully recorded, the brazen circle, with which that useful work was done, may moulder, the marble pillar totter on its base, and the astronomer himself only survive in the gratitude of his posterity; but the record remains . . ."

So, in the course of centuries to come, Herschel's instruments may indeed decay; but the work he did with them will be a part of the history of astronomy for all time.

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